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Twenty-third Convention,
Chicago, Ill.,
May 22, 23, 24, '00.

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NATIONAL

Electric Light

ASSOCIATION

TWENTY-THIRD CONVENTION

CHICAGO, ILL.
MAY 22d, 23d, 24th, 1900

PUBLISHED BY ORDER OF THE EXECUTIVE COMMITTEE

NEW YORK
JAMES KEMPSTER PRINTING COMPANY
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1900

NATIONAL
Electric Light
ASSOCIATION

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Fifth	Philadelphia, February 15, 16, 17, 1887
Sixth	Boston, August 9, 10, 11, 1887
Seventh	Pittsburg, February 21, 22, 23, 1888
Eighth	New York, August 29, 30, 31, 1888
Ninth	Chicago, February 19, 20, 21, 1889
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Eleventh	Kansas City, February 11, 12, 13, 14, 1890
Twelfth	Cape May, August 19, 20, 21, 1890
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Twenty-first	Chicago, June 7, 8, 9, 1898.
Twenty-second	New York, May 23, 24, 25, 1899
Twenty-third	Chicago, May 22, 23, 24, 1900

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Elected at the Twenty-first to serve until the close of the Twenty-fourth Convention.

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F. A. Copeland.*

Elected at the Twenty-second to serve until the close of the Twenty-fifth Convention.

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William M. Brock
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Elected at the Twenty-third to serve until the close of the Twenty-sixth Convention.

Charles B. Hunt
Henry L. Doherty
Ernest H. Davis

---

* Elected in place of F. A. Gilbert, promoted.

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ORDER OF BUSINESS

TUESDAY, May 22d, 1900

FIRST SESSION, 11 A. M.

1. President's Address
2. Announcements
3. Report: Committee for Investigating the Photometric Values of Arc Lamps

SECOND SESSION, 2.45 P. M.

1. Paper: "Utilization of Exhaust Steam for Heating." By HARRY J. FRITH
2. Paper: "Operating Economies in Central-Station Practice." By W. L. ABBOTT
3. Report: Committee on Standardization of Electrical Apparatus

MINUTES

OPENING OF THE CONVENTION

The twenty-third convention of the National Electric Light Association was called to order by President Carnes, at eleven o'clock a. m., May 22d, 1900, at the Auditorium Hotel, Chicago.

Secretary Porter being unavoidably absent, Mr. Ernest H. Davis, on motion of Mr. Neal, was chosen to act as temporary secretary.

THE PRESIDENT: Gentlemen, appreciating the great amount of business we have before us, I have thought it best to spare you the necessity of listening to a long and tedious address and to proceed to business in as short a space of time as possible. I have, however, prepared a very brief address.

President Carnes then presented the following address:

ADDRESS OF THE PRESIDENT

Fellow Members of the National Electric Light Association and Gentlemen: In opening the session of the twenty-third convention, I congratulate you upon meeting again, for the fourth time, in the great city of Chicago; for, aside from the natural advantages of these regular meetings for the discussion of the various practical questions that most deeply interest us, and the further advantages of absorbing the ideas and practices of the most advanced and scientific workers in this most wonderful branch of modern science, we have here in this great city these most advanced developments and up-to-date ideas practically illustrated in a manner most satisfactory to the inquiring mind of the average central-station manager, who in the majority of cases, perhaps, holds his position, not for his original knowledge of the science, but for his ability to utilize the knowledge thus absorbed for the benefit of his stockholders, whose investments are made solely with a view to the returns.

I am sensible of the contrast between this session and our previous meetings, and especially the twenty-first and twenty-second, just preceding, when we were presided over by gentlemen of marked ability and scientific attainments, whose opinions carried all the weight and value to which their own eminent success entitled them, while your present presiding officer represents that class of smaller central-station managers, and while something of a veteran in the business management, he is yet a neophyte in the science.

I appreciate to the fullest extent the compliment of being placed at the head of this organization, although I accepted it as one to my section of the country—the South—and not to myself individually, for I am fully cognizant of my inability to reflect any credit upon the organization which has already reached such a high standard. My case is not so exaggerated, perhaps, but it reminds me of the story of the country boy whose father took him to the city for the first time. He explained to the boy that there was a great difference between the manners and customs of the people of the metropolis and those in the rural districts, and warned him that while he must see and hear all that passed, he must refrain from talking or engaging in conversation lest it might be discovered that he was a green country fool. The boy, fully impressed with this advice, resolved to follow it implicitly. A good-natured city gentleman, observing the verdant hue of this somewhat remarkable-looking provincial, was curious to know something of his origin and history, and undertook to engage him in conversation. He applied a number of questions, but, while the boy looked rather intelligently at him, he made no answer. Finally the man asked him, "Are you deaf and dumb?" The boy shook his head, but answered not a word. "Then you must be a fool," said the man. "There, now, dad," cried the boy, "they have found me out already, and I never opened my mouth!"

Your indiscreet indulgence in this compliment at the expense of your better judgment constrains me to confess that I became sufficiently inoculated with the same unaccountable nerve to entertain seriously the idea of making an effort to deprive you of the advantages of meeting in Chicago by calling this meeting in my own native city of Memphis, with naught to recommend it save its natural southern hospitality, warm as its summer sun, genuine as its native corn juice, and as refreshing as its world-renowned mint; the combination of which has the happy tendency to produce an absolutely irresistible power factor in the establishment of fraternal affection and brotherly love. More mature reflections, however, convinced me that I should have to deprive myself of the pleasure of showing you the livest city in the South, by consulting your better interests and coming to Chicago as originally intended. By this I am sure we have lost nothing, for I find that the wideawake, up-to-date, progressive, whole-souled, all-around good fellows of the electrical fraternity here have, with their usual enterprise and accustomed hospitality, made every provision for our entertainment and pleasure; and I predict that when the programme is announced the power factor of good fellowship will be so firmly established, with the same high efficiency that has always characterized this famous city, that we shall be unanimous in offering the least possible resistance.

Believing that the papers that have been prepared by several gentlemen in response to earnest request will cover subjects of most interest to the greatest number present at this time, I refrain from offering you any further recommendations than a careful consideration and a free discussion of them.

I now declare this convention formally opened.

ANNOUNCEMENTS

Acting-Secretary Davis read letters of regret, as follows, from gentlemen who were unable to be present at the meeting:

"LYNN, MASS., May 1st, 1900.

"S. T. CARNES,
"President National Electric Light Association,
"Memphis, Tenn.

"DEAR SIR: I have received yours of April 20th, and thank you for the cordial invitation extended.

"I hardly think it will be possible for me to be in Chicago on the dates mentioned, as I have matters which will take me away from here a day or two later in a different direction, and my time is very much crowded with work.

"I wish for the meeting every success, and greatly regret my inability to be present.

"Yours very truly,
"ELIHU THOMPSON."

"46 AND 48 EAST HOUSTON STREET,
"NEW YORK, April 24th, 1900.

"MR. S. T. CARNES,
"President National Electric Light Association,
"300 Second Street, Memphis, Tenn.

"DEAR SIR: I wish to acknowledge the receipt of your favor of April 20th, and thank you for the courtesy shown, of which, to my great regret, I shall be unable to avail myself, as pressing duties claim every one of my moments.

"Wishing the association a most enjoyable and profitable meeting, I remain

"Yours very truly,
"N. TESLA."

"BROOKLYN, N. Y., May 18th, 1900.

"HON. S. T. CARNES,
"President National Electric Light Association,
"Auditorium Hotel, Chicago, Ill.

"MY DEAR SIR: I regret exceedingly that I shall be unable to attend the twenty-third convention of the National Electric Light Association, but my business engagements here will not permit.

"I trust you will have a very successful meeting, and I am disappointed not to be able to hear read and discussed the very interesting papers on the programme.

"With kind regards,

"Yours very truly,
"E. F. PECK."

"LONDON, May 4th, 1900.

"S. T. CARNES,
"National Electric Light Association,
"136 Liberty Street, New York.

"DEAR SIR: Allow me to thank you on behalf of my father for your invitation to the next meeting of your association.

"My father is at present in South Africa, and will therefore be unable to attend.

"Yours truly,
"C. CROMPTON."

"CORNELL UNIVERSITY,
"ITHACA, N. Y., April 25th, 1900.

"S. T. CARNES, ESQ.,
"President National Electric Light Association,
"300 Second Street, Memphis, Tenn.

"DEAR SIR: Your letter of April 20th, inviting me to attend the meeting of the National Electric Light Association in Chicago May 22d, 23d and 24th, was duly received. It is a matter of great regret to me that I shall be unable to be present at this meeting of the association. I thank you heartily for the invitation.

"Yours very truly,
"EDW. L. NICHOLS."

"McGILL UNIVERSITY,
"MONTREAL, May 1st, 1900.

"S. T. CARNES, ESQ.,
"President National Electric Light Association,
"Memphis, Tenn., U. S. A.

"DEAR SIR: I have to thank you for your very kind invitation to be present at the meeting of the National Electric Light Association in Chicago on May 22d, 23d and 24th. Although my plans are not yet very definite, I shall hope to do myself the pleasure of being present at this meeting. I am

"Yours truly,
"HENRY T. BOVEY."

Secretary Davis also read an invitation from President Samuel Insull of the Chicago Edison Company, inviting the delegates to visit the new building of that company at 139 Adams street, at any time during their stay in the city, saying that they would be afforded every opportunity to look into the method of conducting the business, and would receive such explanations and information as they might require.

PRESIDENT CARNES: Gentlemen, I would suggest to those of you that have not been through the building that you will find it will repay you for your time. It is a model, in my opinion.

The first business before the meeting is the report of the committee on the photometric value of arc lamps.

The following report was read, in part, by Mr. Henry L. Doherty, chairman of the committee; Professor C. P. Mathews and Mr. James Blake Cahoon, vice-president of the association:

REPORT OF THE COMMITTEE FOR INVESTIGATING THE PHOTOMETRIC VALUES OF ARC LAMPS

Mr. President and Gentlemen of the National Electric Light Association:

Your committee appointed to investigate the photometric value of arc lamps, submits to you herewith a progress report of the work that has been accomplished up to this time.

The committee organized during the early part of September by correspondence, as it has been impossible for it to hold any meetings at which all of the members could be present. It proceeded immediately to the discussion of the work intrusted to its care, to a consideration of the tests which it was desirable should be made, and to providing ways and means for carrying such tests into effect. The result of its labors, in view of the generous assistance and support it has received from all sides, is gratifying; and your committee is able to give at this time the results of a broader investigation than it originally hoped to be able to compass previous to the present convention.

As the committee had at its disposal no instruments or laboratory facilities, by the aid of which it could carry out any experimental investigation, it was glad to secure the cooperation and to accept the invitation of Purdue University to carry on its investigations in the laboratories of the school of Electrical Engineering. The efforts of the committee resulted in the University's placing at its disposal the use of a large laboratory room, containing about a thousand square feet of floor space. The University further provided the committee with facilities in the way of power for conducting tests, and the use of such of the laboratory instruments of the school as could be made valuable in the special work which the committee desired to carry on.

Having in part disposed of the matter of experimental facilities, the committee set about formulating a definite plan for carrying out such a systematic study of the inclosed arc lamp as it deemed would be of greatest value to the membership of the association, and the result of this work was to provide for the following series of investigations, to be carried out and reported upon in the order in which they are named and as rapidly as they could be completed:

First—An investigation to determine the relative merits of the several direct-current inclosed arc lamps at present on the market.

Second—An investigation to determine the relative merits of the several alternating-current inclosed arc lamps at present on the market.

Third—A report upon the relative merits of the alternating and direct-current inclosed arc lamps.

Fourth—An investigation of the coating on the inner globes of direct-current inclosed arc lamps.

Fifth—An investigation of the coating on the inner globes of alternating-current inclosed arc lamps.

Sixth—A report upon the effect of using inner globes of the same shape, but differing in volume, upon the same lamp.

Seventh—A report upon the effect of using inner globes having the same volume but differing in shape.

Eighth—A report upon the life economy of the several brands of foreign and domestic arc-light carbons now in commercial use.

Ninth—An investigation of the actual illumination in streets where only incandescent lamps are used.

Tenth—An investigation of the actual illumination in streets where only open arcs are used.

Eleventh—An investigation of the actual illumination in streets where only inclosed arcs are used.

Twelfth—An investigation of the effect upon illumination of the reflecting power of street fronts, as determined by arranging artificial screens in solid colors to represent the sides of the streets, placing the screens in different tests at different distances apart and in parallel lines.

Investigations 1, 2 and 3 to be made with the lamps working under the exact conditions specified by the makers, and to include life tests of carbons and test for globe coatings.

Investigations 5, 6, 7 and 8 to be made with the aid of the following special material:

(*a*) Samples of all brands of commercial carbons manufactured for inclosed arc lamps.

(*b*) Globes of a variety of shapes and volumes made to fit one make of lamp, number and kind to be specified, in number between twelve and eighteen different globes.

(*c*) Six direct-current inclosed arc lamps of the same make.

(*d*) Six alternating-current inclosed arc lamps of the same make.

(*e*) Clutches for the lamps mentioned in (*c*) and (*d*) to fit the carbons mentioned in (*a*).

Investigations 9, 10 and 11 to be made upon the same street by changing the lamps on a given street, and with the aid of special photometric apparatus to be designed.

Investigation No. 12 to be made on the campus of Purdue University.

To the end of obtaining the direct-current and alternating-current inclosed arc lamps necessary for carrying out these tests, the committee corresponded with the manufacturers of inclosed arc lamps, and, as a result, secured the following number of lamps, which were shipped to the electrical laboratory of Purdue University.

The Adams-Bagnall Electric Company supplied one direct-current inclosed arc lamp, one alternating-current inclosed arc lamp, six inner globes, four outer globes, one open arc lamp with globe, and carbons.

The Helios-Upton Company supplied one direct-current inclosed arc lamp, one alternating-current inclosed arc lamp, twenty inner globes, six outer globes, and carbons.

The Manhattan General Construction Company supplied one direct-current inclosed arc lamp, one alternating-current inclosed arc lamp, twenty-two inner globes, four outer globes, and carbons.

The General Electric Company supplied one direct-current inclosed arc lamp, one alternating-current inclosed arc lamp, four inner globes, two outer globes, one open arc lamp with globe, and carbons.

The Jandus Electric Company supplied one direct-current inclosed arc lamp, one alternating-current inclosed arc lamp, eighteen inner globes, four outer globes, and carbons.

The General Incandescent Arc Lamp Company supplied one direct-current inclosed arc lamp, one alternating-current inclosed arc lamp, twelve inner globes, two outer globes, and carbons.

The C. J. Toerring Company supplied one direct-current inclosed arc lamp, six inner globes, two outer globes, and carbons.

The Sterling Arc Lamp Company supplied one direct-current inclosed arc lamp, one alternating-current inclosed arc lamp, twelve inner globes, two outer globes, and carbons.

The Lea Manufacturing Company supplied one direct-current inclosed arc lamp, one alternating-current inclosed arc lamp, five inner globes, two outer globes, and carbons.

The Standard Thermometer and Electric Company supplied one direct-current inclosed arc lamp, one alternating-current inclosed arc lamp, eight inner globes, three outer globes, and carbons.

The committee has also corresponded with the manufacturers of carbons, and has received favorable replies and the shipment of samples from

Schiff, Jordan and Company, manufacturing the "Ship" carbon; the Hugo Reisinger Company, handling the "Electra" carbon; and the National Carbon Company, manufacturing the "Columbia" carbon.

The names of the manufacturing companies who have kindly assisted the committee in advancing this work are given here, in acknowledgment of the services which they have rendered. The tests upon the various lamps, etc., contained in the report have been reported by number only, the names of the manufacturers not being attached.

In carrying out the investigations as planned, it is needless to say a large amount of labor is involved, and therefore it was thought wise to provide such special appliances as possible to enable the experimenters to perform their work with the least possible expenditure of energy. To this end, the committee has been able, through the generosity of members of this association that have contributed to the arc-light fund, and others, to provide certain special apparatus, which will be found described in detail in the attached progress report. In this report results are recorded on only the first five of the series of tests contemplated and enumerated above.

The thanks of this committee are especially due to the officers of Purdue University, for providing a laboratory for its investigations, and to the faculty of the School of Electrical Engineering of Purdue University for the great service rendered in conducting the tests planned by the committee.

(Signed) HENRY L. DOHERTY, Chairman.
W. ELWELL GOLDSBOROUGH.
J. Q. BROWN.

TREASURER'S REPORT

MR. HENRY L. DOHERTY,
Chairman of the Committee on Arc Light Photometry.

DEAR SIR: As acting treasurer of your committee I submit a report of monies received and expended by me in behalf of your committee.

DR.

Amount secured for use by the committee, independently	$434 01
Amount of Arc Light Fund received by drafts from the Treasurer of the National Electric Light Association, to be applied to the expenses of the committee in conducting tests	390 00
Total	$824 01

CR.

Lumber, paint, and materials used in fitting up laboratory for photometric research work	$307 65
Labor of painters, carpenters and wiremen in fitting up laboratory	112 36
Switchboard and terminal lines	14 00
1 Lummer–Brodhun Photometer	67 75
1 Spherical C. P. Photometer	61 73
1 Illuminometer	15 00
1 Photometer Recorder	20 29
4 Arc Lamp Testing Racks	28 20
1 Lamp Crane	17 00
Bunsen Photometer Screens	3 04
Mirrors for Photometer	5 40
Special photometric incandescent lamps	4 45
Iron fittings for Photometer	17 07
Switchboard fittings and appliances	16 00
Wire, incandescent lamps and fittings	51 55
Lumber for making cases	13 19
Extra help in working up results	6 00
Balance	63 33
Total	$824 01

W. ELWELL GOLDSBOROUGH,
Acting Treasurer of Committee on Arc Light Photometry.

To the Committee of the National Electric Light Association on the Photometric Value of Arc Lamps:

I take pleasure in transmitting to you herewith a progress report on the photometric tests of inclosed arc lamps, which I have received from Professor Matthews. The experimental work has been carried out as nearly as possible in accordance with the wishes of the committee, and, to this end, Professor Matthews has held frequent consultations with myself during the progress of the work.

I have been glad to place at the disposal of the committee the services of our engineer, wireman and carpenter, in assisting the experimenters, in so far as not to interfere markedly with their regular duties, and, in consequence, the experimenting has been facilitated, in view of the more ready adjustment of apparatus and circuits.

The work has progressed steadily since the completion of the fitting up of the special laboratory about the middle of January. A slight embarrassment was occasioned on account of delay on the part of some of the manufacturers in the shipment of lamps; a delay, however, on account of their factories being overcrowded with orders.

Professor Matthews, in whose care I have placed the direct supervision of the tests, and his six assistant experimenters have labored very faithfully in carrying out the investigations, and have done a large amount of work, of which no record is made, in devising ways and means for eliminating errors and conducting lamp tests rapidly. A number of pieces of special apparatus have been devised, designed and constructed for this purpose with your approval, and I feel that the element of personal error has entered but slightly into the work in consequence. An important step in advance is made in view of Professor Matthews' appliances for reducing the error due to the wandering of the arc, and for practically eliminating the matter of color difference between standard and source in the photometric tests on the arc.

To admit of the work's being completed on the first five of the series of tests provided for, the running schedule of our lighting plant has been increased from ten to fifteen hours a day, and from five to twelve of the inclosed arc lamps have been kept busy during this time.

I trust that the results will be found to be in every way satisfactory to you and to the association.

Yours very truly,

W. ELWELL GOLDSBOROUGH,
Director of the Electrical Laboratory,
Purdue University.

PROFESSOR W. E. GOLDSBOROUGH,
Director of the Electrical Laboratory, Purdue University, Lafayette, Ind.

DEAR SIR: As your committee has decided to make, at this date, a report of progress in the matter of inclosed-arc-lamp testing, I beg to submit below certain data that have been obtained since the work was taken in hand. Owing to the extensive character of the tests outlined by your committee, I have thought it desirable to perfect the method as much as possible. This has not been done without the loss of much time at the outset, but I am confident that subsequent progress will, as a result, be the more rapid and satisfactory. You are, of course, aware of the many preliminaries and the large amount of detail involved in any work of this character. After the tests are well started, the necessity of taking many readings results in an accumulation of data, which can be put into final shape only through the expenditure of much time and labor. However, I trust that sufficient has been accomplished to demonstrate that the wishes of your committee are being carried out, and that substantial progress is being made.

For the sake of clearness and brevity, the subject matter will be taken up formally under headings as follows:

ACKNOWLEDGMENT

In the conduct of this work I have had the active assistance of six members of the present graduating class at Purdue University: Messrs. G. H. Kelsay, A. B. Golden, L. W. Cromwell, O. F. Slimp, C. Branigan and P. B. Sawyer. Mr. E. T. Mug, assistant in the department, has rendered timely aid in calculations and drawings.

ADJUSTMENT OF LAMPS

In order to handle the lamps easily a special suspension is used (Figure 1). This arrangement serves at once as a hanger and as means of conducting current to the lamp. A number of iron racks shown in section at LL are provided with pins, over which are slipped the washers (w). The photometer room is provided with a similar set of pins; hence, to remove a lamp from the adjustment rack and put it in position for a test is a matter of only a few minutes. The screw and nut T enable one to center

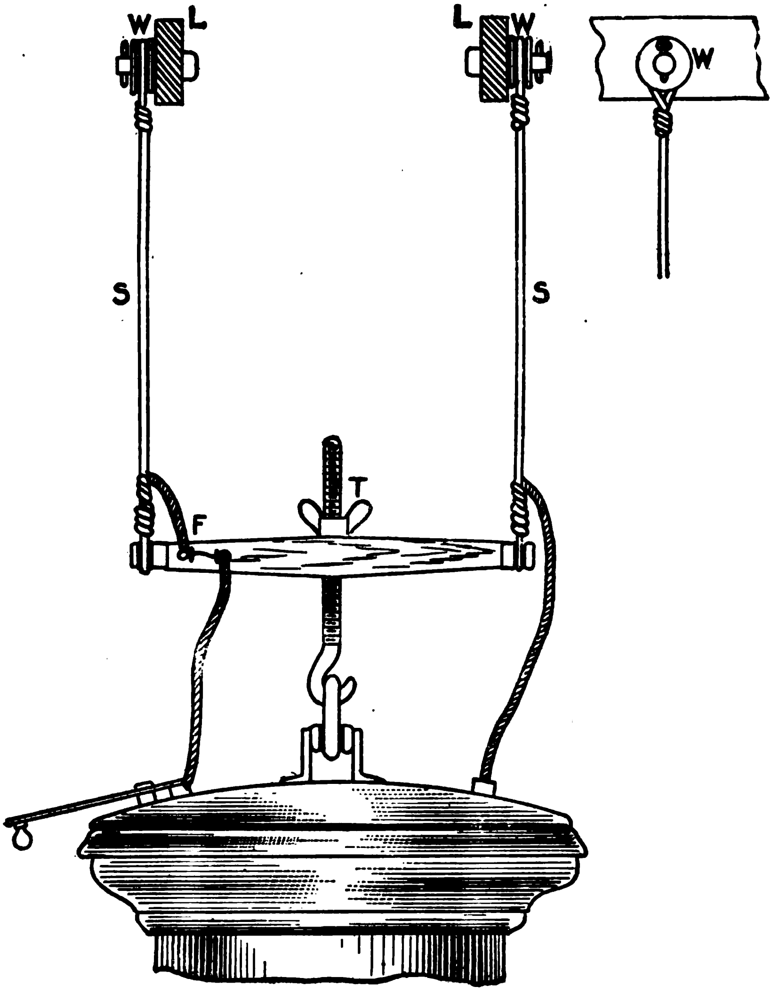

FIG. 1.—SHOWING METHOD OF SUSPENSION.

the arc accurately with reference to the system of mirrors.

Figure 2 shows a set of twelve lamps on a time test. The six lamps in the foreground are on a direct-current circuit; the remaining six are on an alternating-current circuit.

Figures 3 and 4 show two views of the adjustment room in the Photometric Laboratory. Here are seen racks for globes, the switchboard, and other accessories. In the background of Figure 3 is seen a series of the paper records taken from the recording drum described further on.

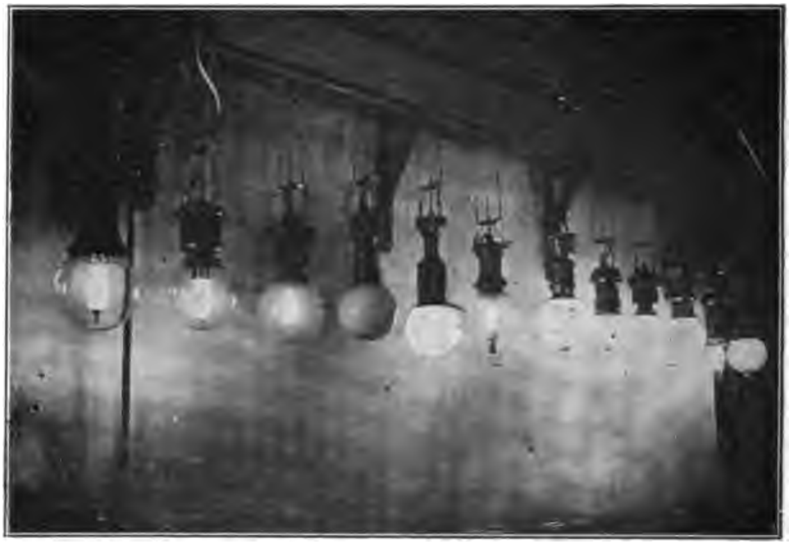

FIG. 2.—LAMPS SUSPENDED FROM RACKS AND UNDER A TIME TEST—ELEVEN LAMPS BURNING.

In Figure 5 are seen different types of inner globes. As to the opening, there are two general classes of these globes:

1. Globes that surround the side rod or rods, and have an opening at the top only, and

2. Globes that do not surround such rod or rods, and that have, in consequence, an opening at both

top and bottom. These two classes are to be found in the upper and lower rows respectively.

As to transparency, one may distinguish several kinds, as follows, counting from the upper left-hand corner:

Clear, Nos. 1, 4, 7, 9, 12.
Milky, Nos. 2, 6, 8.
Opalescent, Nos. 5, 10, 13.
Ground, Nos. 3, 11.

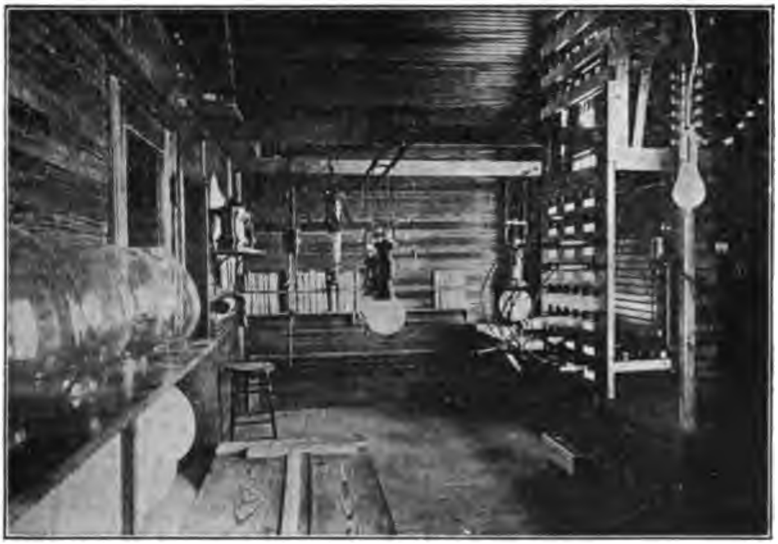

FIG. 3.—PHOTOMETRIC LABORATORY, ADJUSTMENT ROOM.

The remark may be made that globes of the type styled "opalescent" vary considerably in translucency, and many of them may be classed as on the border line between the classes "opalescent" and "milky."

THE PHOTOMETRY OF THE ARC

In a paper* heretofore published, I have summarized the causes of error and uncertainty in arc-light photometry. As these matters are patent enough to any one that has had experience in such work, I will not go into a detailed recapitulation of them here, except in so far as a description of certain methods and devices intended to minimize such errors and uncertainties may seem to necessitate. If one compares the results obtained by different investigators on the luminous intensity of the arc, he finds large discrepancies. Indeed, so discordant are the results that the opinion has been advanced by some that such measurements are almost worthless, and that any attempt to obtain consistent and reliable data on the luminous intensity of the arc might well be abandoned at the outset. This is undoubtedly an extreme view, and, personally, I do not share it. We have to consider the question:

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* Transactions A. I. E. E., XV, 599, 1898.

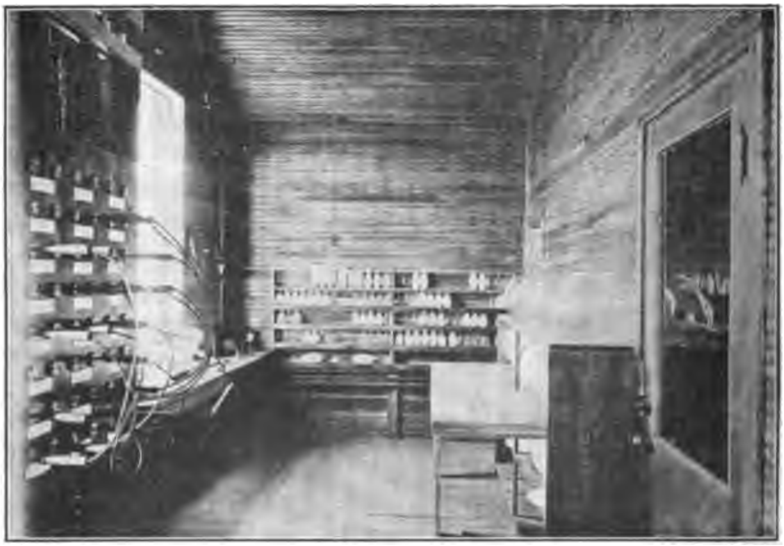

FIG. 4.—PHOTOMETRIC LABORATORY, ADJUSTMENT ROOM.

With what degree of accuracy shall we be content? Anything comparable with the accuracy to be obtained in purely electrical measurements is not to be thought of. On the other hand, that the results from different tests should be concordant to a degree no better than fifty per cent would seem to indicate either that such tests have been made under widely different conditions—that is to say, as to carbons, globes, etc.—or that sufficient time and study have not been bestowed on the methods employed. I am of the opinion that an absolute accuracy of less than ten per cent and a relative accuracy in any one series of tests of less than five per cent are quite within the range of possibility.

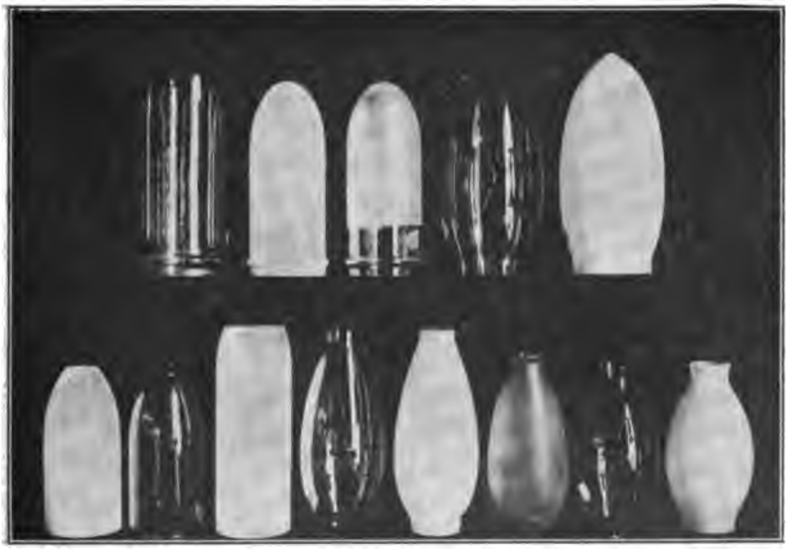

FIG. 5. TYPES OF INNER GLOBES.

It is apparent that the difficulties met in the pursuit of good results in arc-light photometry may be classified under two heads:

First—Those peculiar to the source, and,

Second—Those peculiar to the method.

Of the first class, none is more troublesome than the great change in the intensity in any given direction, due to the wandering of the arc over the surface of the carbon tips. For instance, if the arc shifts suddenly from the remote side of the carbons to the side towards the photometer, the resulting change in luminous intensity may be 200 per cent. Under these circumstances, the only hope of getting a value representing the mean intensity, at least with the use of one photometer arranged in the ordinary way, lies in taking a relatively great number of readings referred to time, and in integrating the result.

To accomplish this, I have employed, and described elsewhere,* a device to record the settings mechanically. While this is a labor-saving device, it does not obviate the necessity of taking many settings, nor lessen the number of computations. Since taking up the work for your committee, I have constructed a piece of apparatus that greatly reduces the fluctuation in the illumination on the photometer disc, and hence gives a good result with a greatly diminished number of settings. The method involved may be well designated as the *double-mirror method*, and is, so far as I know, new.† It consists in nothing more than the employment of two mirrors instead of one, and in taking light simultaneously from opposite sides of the arc at the same inclination to the vertical, both mirrors being capable of ready adjustment at any angle in the vertical plane. The arrangement of apparatus for carrying out this plan is shown, somewhat diagrammatically, in Figure 6.

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* *Physical Review*, November, 1898.

† Since writing this, I find that the eminent French photometrist, Blondel, has embodied a similar principle in his admirable Photomésomètre.
C. P. M.

The two mirrors, M, M′, are mounted at the extremities of iron arms, and are suitably counterbalanced, as shown. The arc is fixed in the center of rotation at (a), and light is incident upon the photometer disc at (c), by the two paths shown in dotted lines, direct light from the arc being cut out by a screen not shown in the figure. This plan necessitates a fixed photometer, P, and, in order that a variable illumination may be produced to balance that due to the arc, I have arranged a cord and windlass, W, permitting the observer to move with facility the secondary standard, S, which is a glow lamp.

At D is shown a long wooden cylinder, upon which is wrapped the paper to receive the records of the test. These records are made by an electromagnetic device, R, which punctures the paper whenever an electric circuit is closed at the button, B.

The observer, seated before the photometer in a closely screened inclosure, operating with one hand the windlass, and with the other the push-button, is enabled to take settings with relatively great rapidity and accuracy. At a point 200 cm. to the right of the photometer disc, a reserve standard is mounted on an arm that may be swung into a position in line with the bar. This reserve standard was carefully evaluated once for all in terms of the Hefner lamp. To determine the intensity of the secondary standard, S, it is only necessary to turn the reserve into position and record a series of readings in the same way as for the arc. This operation is carried out at the end of each test, or more frequently if any

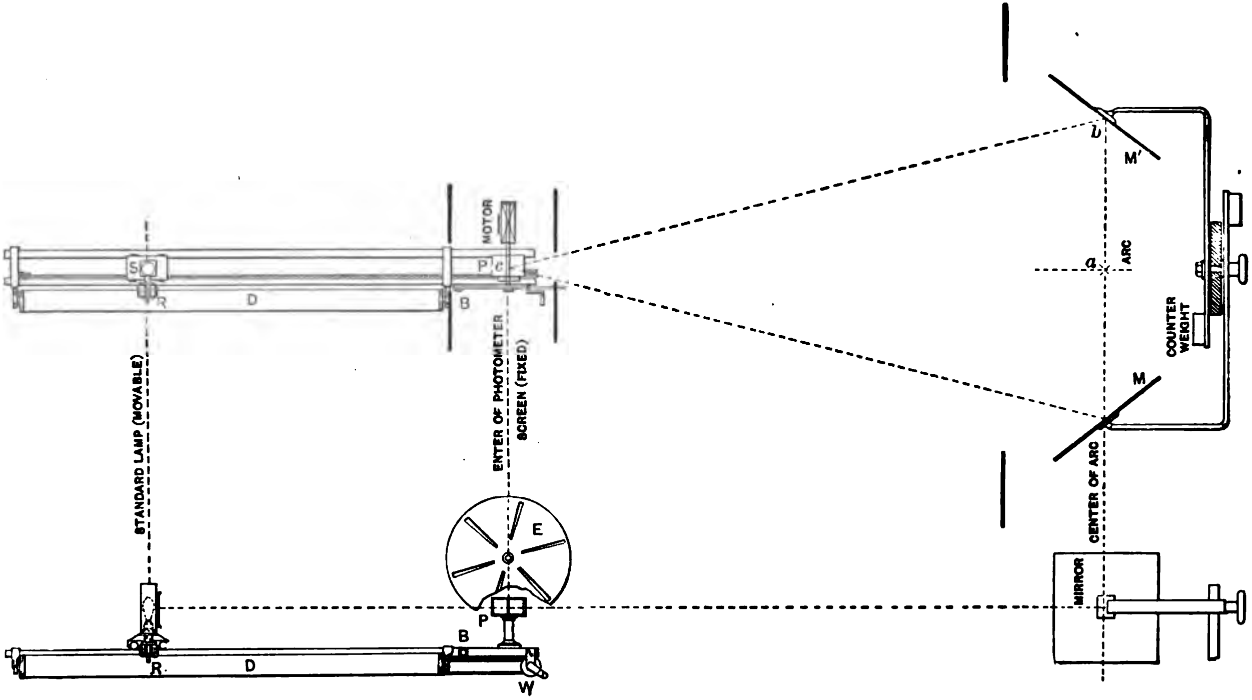

FIG. 6.—APPARATUS FOR THE MEASUREMENT OF LUMINOUS INTENSITY.

change has been made in the temporary standard. Thus, it will be seen that, should the lamp under test be found particularly weak at certain angles, the limit of the bar might be reached in the attempt to get a setting. In such case, it is necessary to stop down the temporary standard and to again refer it to the reserve. I may add that the reserve is never allowed to burn more than a few minutes, and can not possibly deteriorate under such conditions of use.

With this disposition of the mirrors, the angle of incidence at the photometer disc is constant. In Figure 6, this angle is shown at more than twice its actual value, in order to reduce the length of the drawing. The real value of this angle is 5 degrees 54 minutes. To make a correction for this lack of normal incidence would mean the division of the intensities, as found, by the cosine of 5 degrees 54 minutes, or .9947. Failure to do this introduces an error of about one-half of one per cent, which is clearly negligible in work of this character.

If, at a given instant, I' be the intensity of the arc to the left, and I the intensity to the right, d the fixed distance, *abc*, d_s the distance of the movable standard and K the mirror coefficient, we have as the mean intensity,

$$I = \frac{I + I'}{2} = \left[\frac{d^2}{2d_s^2}\right] \times \frac{I_s}{K}$$

The factor in the bracket was computed once for all for values of d_s throughout the range of the bar, and these values were laid off as graduations on a long T-square. To work out the intensities in any particular test, it suffices to pin the record from the drum upon a long table, and to read directly from a

T-square the values of the bracketed expression corresponding to the punctures in the paper. The mean of these values for any one position multiplied by the factor to the right of the bracket gives the intensity for that position in Hefner units.

It is of course, necessary in testing sources with large globes or shades to use mirrors of such size that the globe or shade may be seen in its entirety, when the eye is placed at the point c (Figure 6); and it is further necessary that the distance *abc* should be large.

It is important to note that the double-mirror method, while enormously diminishing the fluctuation due to wandering of the arc, can have no effect on such fluctuations as are due to variations in length of the arc, or to variations in the current strength. The relative accuracy of the single and double-mirror methods will be brought out in certain data to be found further on.

Of the difficulties peculiar to the method, the most serious arises from the attempt to compare the arc with a standard of different color. It is well known that when the color difference is marked the setting partakes of the nature of a guess, differing not only with different observers, but with the same observer at different times. To minimize the error due to this cause, I have made use of the physiological fact that, as the illumination of two surfaces tends toward zero, the eye appreciates their difference in color to a less and less degree, and is thus able to estimate an equality in luminosity unhampered by the sensation of color. Thus, the method of winking, or half-closing the eyes, has been used by many experimenters to diminish the color sensation. These latter processes are very fatiguing to the observer, and

I have adopted the plan of diminishing the intensity of the photometric field by the use of a rotating sectored disc E (Figure 6) of very small angular opening. Ferry has found that the use of the sectored disc to reduce the intensity of *one* source in comparison with another of different color introduces an error, because the ratio of the light transmitted to light cut off does not appear to be the ratio of the open to the closed sectors when the opening is small. It will be noted that the disc in the figure is so placed as to diminish equally both sides of the photometric field, and hence one would not look for an error of this character.

To test the accuracy of these methods with different observers, I operated upon an automatic feed, inclosed arc in exactly the manner that has prevailed throughout the tests, and requested four observers, whom I will designate by S, G, K and F, to make nine settings each. The mean results are:

S	G	K	F
813	808	852	845

These are the light ratios multiplied by a constant. The mean of all is 830. Hence, the individual means differ from the mean of all by:

S	G	K	F
−2%	−2.6%	+ 2.6%	+ 1.8%

As these settings lay in nearly the same range on the recording drum, I inferred that a part of the variation was due to an insufficient number of settings.

Subsequently, observers M and K, who have made all the settings in the arc-light tests that follow, took a greater number of settings, with the following results:

M (16 settings)	K (14 settings)
770	775

This agreement of 0.7 per cent is so close that I am inclined to regard it as somewhat fortuitous, but one may safely conclude that the error due to the personal equation of the observer is little greater when this method is used than it is in the comparison of sources of like color.

As to the error due to fluctuation, I had previously taken, by the single-mirror method and the recording drum, seventy-one settings in a particular direction. Taking now as a *fluctuation factor the mean deviation from mean* of these seventy-one settings, and disregarding signs, one obtains

Mean intensity × a constant=92.9
Fluctuation factor =29.6= 32 per cent.
Maximum deviation =99 =106 "

With the double-mirror method the mean of the thirty values obtained by K and M gives:

Mean intensity × a constant=772
Fluctuation factor = 69.5= 9 per cent.
Maximum deviation =268 =34.7 "

or, in a word, the fluctuation with the single-mirror method is more than thrice that with the double-mirror method.

UNITS

The values of luminous intensity in these tests are expressed in terms of the Hefner amylacetate lamp. They may be reduced to British candles by multiplying by the factor .88. I would call attention, however, to the fact that this is little more than multiplying by an arbitrary constant, since no one knows definitely what the luminous intensity of the British candle is. On the other hand, the Hefner unit has met with an international sanction, and is quite generally accepted as a unit, far from perfect, but possessing, especially for practical purposes, fewer faults than any unit thus far proposed.

I trust that the association may see fit to adopt a complete system of photometric units, as proposed by M. Blondel. There is particular need that a unit of *luminous flux* should receive general acceptance.

SPECIAL TEST

When an opalescent inner globe is used, the globe itself becomes more or less luminous by diffusion. The diffusion differs with the height of the arc in the globe, that is to say, with the length of the lower carbon. To ascertain the magnitude of this effect, I have carried through three tests on the same lamp and inner globe, and also the same carbons, the lower carbons being cut successively to the lengths four and three-quarter, two and three-quarter and one and one-quarter inches. The results appear in Table 1 and Figure 7. In every case the arc was placed at the center of the mirror system.

An inspection of these results shows that least light is obtained with the arc at the top of the globe, and most light when the arc is at the mid-point. This is explained in part by the fact that with the arc at the top a good part of the luminous flux is incident upon the non-reflecting surface of the gas cap.

While the second and third positions yield a considerably increased flux of light with a clean globe, they must be considered as impossible conditions in practice, since, by the time the arc has descended to these points, the globe has received a coating. The net result then, as the lamp burns, is due to an increase in light flux due to the descending arc, and a diminution in light flux due to the formation of a coating. How this affects the quantity of light emitted—that is, the product of flux and time integrated throughout the life of the carbons—is a subject for future investigation, and involves the questions of carbons, shape of globe, etc.

TABLE 1

Special test, showing effect of height of arc in globe

Angle	4¾ inches	2¾ inches	1¼ inches
59° A	61.3	(55A) 88.1	
50 A	129.1	122.2	132.7
40 A	190.6	209.4	149.1
30 A	169.5	214.6	173.5
20 A	215.6	273.5	269.4
10 A	234.0	265.1	247.8
Hor.	215.5	296.3	252.3
10 B	277.8	369.5	372.3
20 B	291.7	423.9	388.5
30 B	382.4	448.0	365.9
40 B	354.6	465.8	435.1
50 B	264.3	402.6	353.3
60 B	263.	329.	278.1
70 B	202.9	243.5	197.3
80 B	3.64	36.9	

Globes	Opalescent Inner Only		
Mean hemispherical, upper	178 H. U.	199 H. U.	185 H. U.
Mean hemispherical, lower	288 H. U.	385 H. U.	351 H. U.
Mean spherical	233 H. U.	292 H. U.	268 H. U.

In the tests that follow, I have chosen the initial condition as the simplest to obtain, even though the light emitted may be less than at some subsequent period in the life of the carbons.

Should any one desire to test a lamp for the purpose of obtaining comparative results, he would not be under the necessity of burning the lamp for many

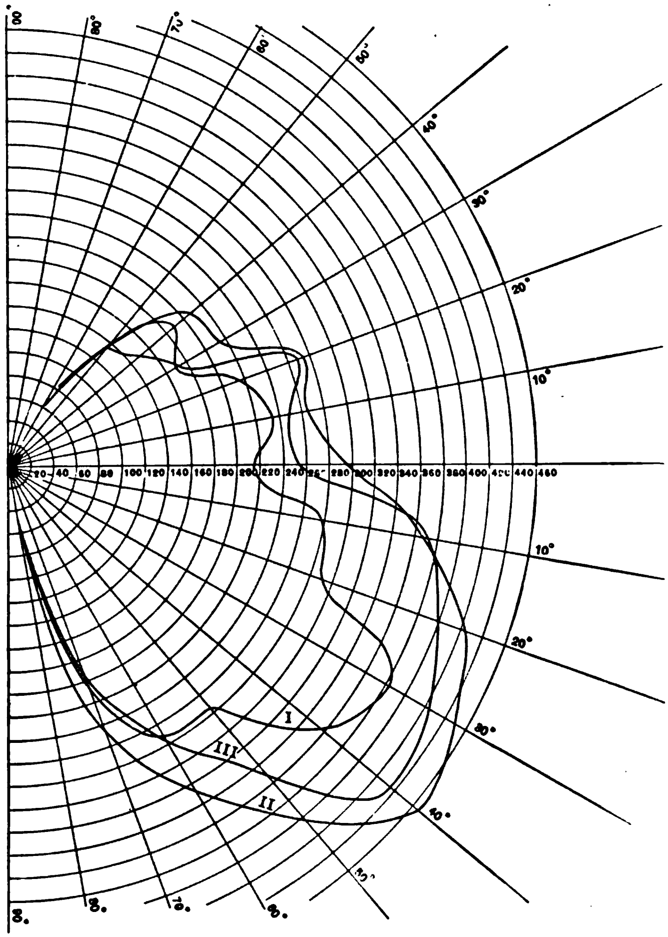

FIG. 7.—VARIATION OF LUMINOUS INTENSITY WITH HEIGHT OF ARC IN A CLEAN OPALESCENT GLOBE.

Curve I.—Lower Carbon, 4¾ in. Curve II.—Lower Carbon, 2¾ in. Curve III.—Lower Carbon, 1¾ in.

hours to get the proper conditions, as he would necessarily have to do were one of the lower positions chosen in these tests.

FIRST INVESTIGATION

In order to determine the status of the direct-current, inclosed arc as found commercially on the market, it seemed desirable to study first the questions of luminous intensity, power consumption and efficiency, taking the lamps as supplied by the makers, but operating under a certain uniformity in conditions. These conditions are

1. The same brand of carbons throughout.
2. An opalescent or milky inner globe, and a clear outer, as supplied.
3. An opalescent inner globe, and an "opal," ground, or milky outer globe, as supplied.

To these, I have added in certain cases a test with no outer globe whatever, in order that the absolute, as well as the relative, absorption of the outer globes might be found.

The lamps are fitted with the proper lengths of carbons, and adjusted, *as nearly as possible*, to the voltage at the arc named in the makers' specifications. They are then allowed to burn until thoroughly heated before the test begins. One observer maintains the terminal electro-motive force constant, and takes readings of the current throughout the test, while another operates the photometer. The values of current given are therefore the mean of many readings.

From the records taken off the recording drum the values in the tables are computed. These values are then plotted in polar co-ordinates, as shown in the curves below, and also in rectangular co-ordinates in the well-known Rousseau diagram, which latter is integrated by the planimeter to get the mean spherical intensity.

In this way eight direct-current, 110-volt lamps have been tested up to the present writing.

Referring to the lamps by number we find the results on Lamp 1 in Table 2, Figure 8.

The curves show very clearly the slight absorption of the clear outer and the large absorption of the opalescent outer. The clear outer globe shows some diffusion, as it tends to round out the curve. Thus there are two regions where curve II extends beyond curve III. In the case of the opalescent outer globe, the diffusion is so marked that the luminous intensity is practically constant throughout a very large solid angle. In the higher angles above the horizontal, the intensity is greatly increased, producing the effect, approximately, of a luminous sphere of equal intrinsic

TABLE 2

LAMP 1

Angle	Test 1	Test 2	Test 3
59° A	109.8		
50 A	140.3	35.	(45A) 54.9
40 A	162.6	85.3	87.2
30 A	169.7	137.7	159.5
20 A	178.5	207.9	223.9
10 A	218.1	246.4	270.2
Hor.	190.9	259.	253.2
10 B	178.3	282.1	334.7
20 B	214.67	370.7	400.1
30 B	191.7	401.6	454.3
40 B	188.2	404.3	432.1
50 B	209.3	346.1	387.1
60 B	134.4	308.	307.1
70 B	114.1	177.8	303.3
80 B	175.2	264.7	101.3

Globes	Op Inner Op. Outer	Op. Inner Clear Outer	Op. Inner No Outer
E. M. F.	110 volts	110 volts	110 volts
Current	4.87 amperes	5.07 amperes	5.08 amperes
Watts	535.7	557.7	558.8
Mean hemispherical intensity	Upper, 159.5 Lower, 186.4	137.5 332.2	149.9 362.4
Mean spherical intensity	172.9	234.8	256.1
Watts per mean H. U.	3.10	2.37	2.18

brightness. This results in the elimination of shadows, and the production of a pleasing light for interiors. The quality of light is also changed to a considerable extent through the absorption of the excess of violet rays otherwise very marked in the light of the arc. This result is attained, however, at a diminished

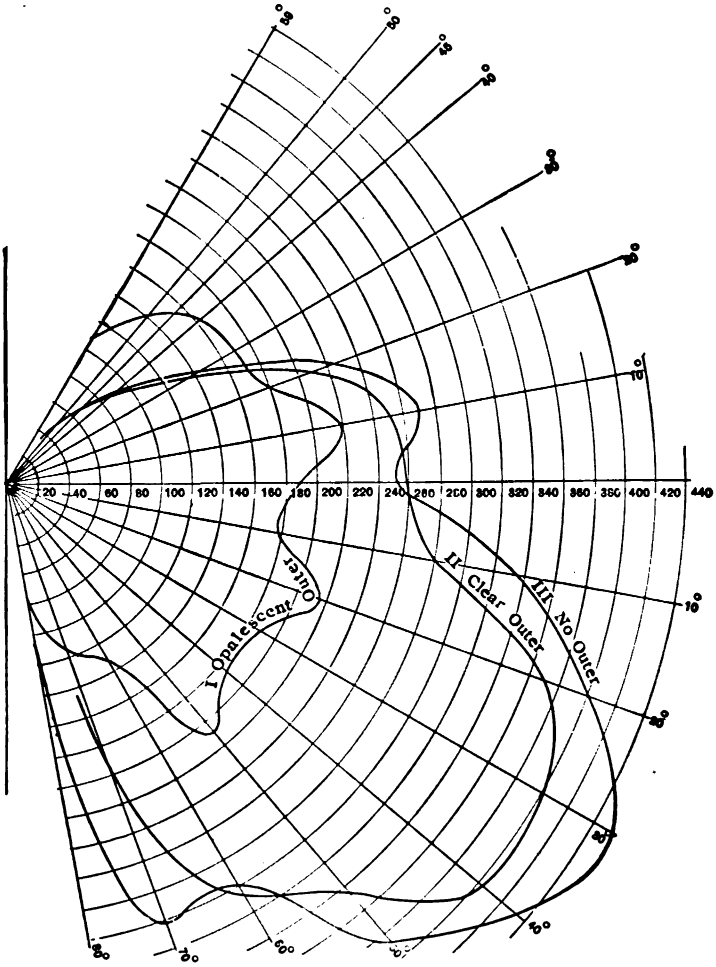

FIG. 8.—LAMP I.

Curve I.—Opalescent Outer Globe. Curve II.—Clear Outer Globe. Curve III.—No Outer Globe.

efficiency. In this and nearly all the curves with the opalescent outer globes, a certain wavy outline is noticed. I think this effect is due, in large part, to the variations in the diffusive power of the globe itself. One finds difference in thickness and translucency to a considerable extent in such globes, and, as the angle of view changes, these differences would tend to distort the distribution curve.

TABLE 3

LAMP 3

Angle	Test 1	Test 2
59° A	(55A) 59.5	87.3
50	102.7	114.7
40	153.7	165.3
30	164.2	182.8
20	203.8	198.1
10	209.3	206.2
Hor.	219.8	222.8
10 B	262.7	239.2
20	273.1	232.6
30	328.7	219.1
40	364.1	241.4
50	315.5	282.1
60	224.8	227.
70	288.6	185.7
80	110.2	165.8

Globes	Op. Inner Clear Outer	Op. Inner Op. Outer
E. M. F.	110 volts	110 volts
Current	5.1 amperes	5. amperes
Watts	561.	550.
Mean hemispherical intensity H. U.	Upper, 150. Lower, 282.	160. 230.
Mean spherical H. U.	216.	195.
Watts per mean spherical	2.60	2.85

In Table 3 and Figure 9 are the results of two tests with the usual combination of globes on lamp 3. In this case the opalescent globe transfers a certain portion of the luminous flux to the upper hemisphere —sufficient, in fact, to throw curve II quite out to the curve obtained with the clear globe.

Following are the data and curves of a test on lamp 4. This lamp is provided with an outer globe of ground glass. The inner globe has straight walls, and with the arc at the top the distribution curve comes out somewhat oddly. The luminous flux above the horizon is very small. The strong intensity at eighty degrees below with the clear outer globe

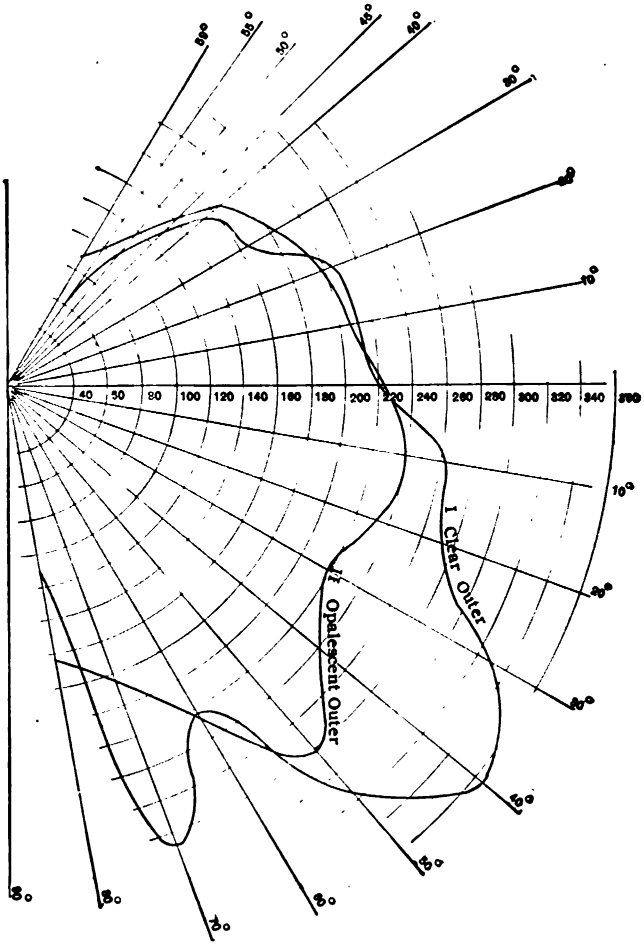

FIG. 9.—LAMP 3.

Curve I.—Opalescent Inner, Clear Outer. Curve II.—Opalescent Inner, Opalescent Outer.

has been found in more than one case under like conditions. I have not been able, thus far, to arrive at a satisfactory explanation of it, but it seems to be associated in some way with a multiple reflection due to the outer globe. Professor Thomas has found similar strong changes in intensity in the case of the slow lamp, due to images of the filament, whose effect becomes very marked at certain angles. It may be that we have a similar phenomenon here.

TABLE 4

Lamp 4

Angle	Test 1	Test 2
59° A		
50	39.5	
40	52.6	
30	81.	28.3
20	107.2	80.4
10	136.7	167.6
Hor.	145.2	213.4
10 B	185.5	231.9
20	199.5	235.
30	185.3	219.9
40	199.	208.9
50	140.3	175.8
60	143.4	176.3
70	192.	168.8
80	104.2	190.5
Globes	Op. Inner Ground Outer	Op. Inner Clear Outer
E. M. F.	110 volts	110 volts
Current	4.76 amperes	4.76 amperes
Watts	523.6	523.6
Mean hemispherical intensity in H. U	Upper, 80.4 Lower, 173.6	70.4 208.
Mean spherical H. U.	127.	139.2
Watts per mean spherical	4.12	3.76

In figures 11, 12, 13, 14 and 15 are found the curves taken on lamps 5, 7, 9, 10 and 12 respectively. The corresponding tables are 5, 6, 7, 8 and 9. These tests are made under the conditions already specified.

The curves differ in detail, but show similar characteristics. In considering them, one should remember that while the lamps have nominally outer globes of

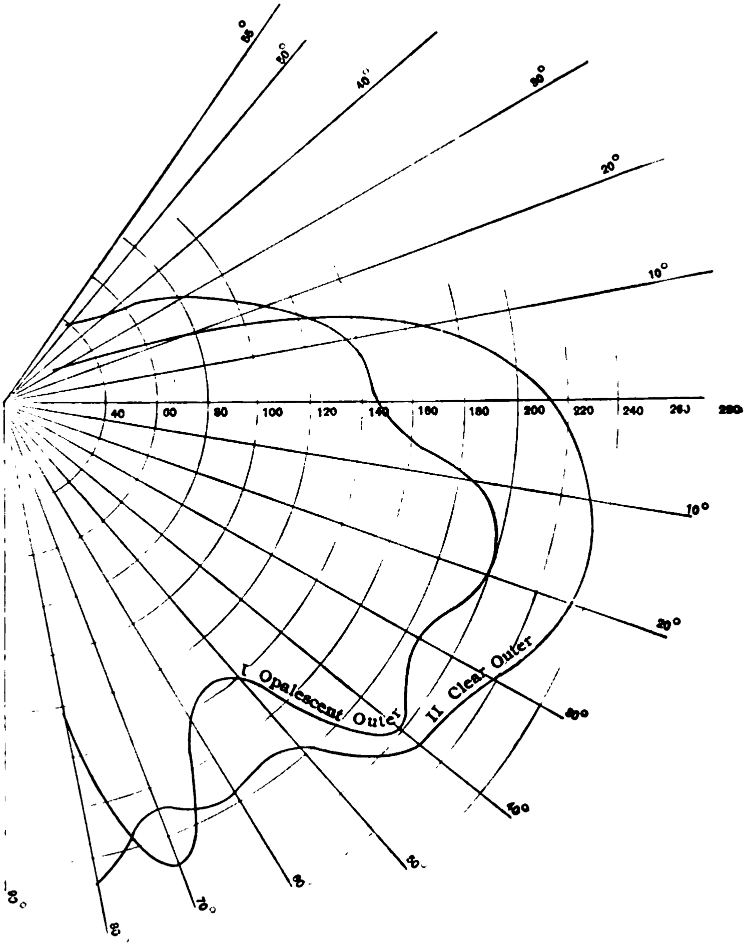

Fig. 10.—Lamp 4.

Curve I.—Ground Outer Globe. Curve II.—Clear Outer Globe.

the same kind, they have markedly different inner globes. Again, some of the lamps have a bright metallic surface above the inner globe. This surface acts to some extent as a reflector. Taking these facts into consideration in connection with the variations in the transparency of different parts of any one outer globe, one can understand why these curves do not more closely follow a general type.

TABLE 5

LAMP 5

Angle	Test 1	Test 2
59° A	91.9	114.5
50	110.4	140.5
40	114.7	134.9
30	157.9	166.7
20	154.5	163.1
10	162.2	177.6
Hor.	160.0	169.1
10 B	206.4	176.2
20	274.6	165.5
30	256.4	179.5
40	263.8	168.9
50	225.3	162.7
60	212.3	162.7
70	105.2	157.2
80	144.7	157.2

Globes	Op. Inner Clear Outer	Op. Inner Op. Outer
E. M. F.	110 volts	110 volts
Current	4.16 amperes	4.16 amperes
Watts	457.6	457.6
Mean hemispherical intensity in H. U.	Upper, 126.6 Lower, 220.8	141.6 167.2
Mean spherical H. U.	173.7	154.4
Watts per mean spherical H. U.	2.63	2.96

I will leave further discussion of the curves showing distribution of luminous intensity until the second and third divisions of this subject, as outlined by your committee, have been taken up, and pass to other matters in a résumé of the results of the first investigation. At a common terminal electro-motive force of 110 volts, seven of these lamps take an average current of 4.90 amperes, which means an average total power consumption in each lamp of 539 watts. With 80 volts at the arc this power is divided into 147

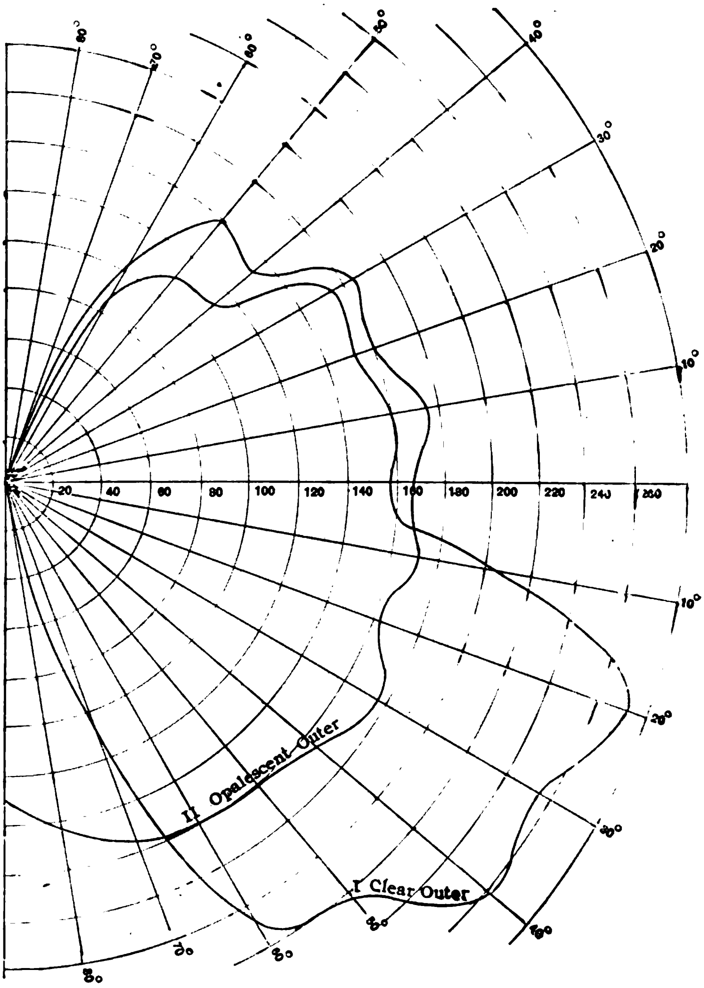

FIG. 11.—LAMP 5.
Curve I.—Clear Outer Globe. Curve II.—Opalescent Outer Globe.

watts waste in the resistance coils and 392 watts in the arc. The average yield of light, expressed as mean spherical intensity, is:

Opalescent inner, no outer* =256 H. U.
" " clear outer =207 H. U.
" " opalescent outer =177 H. U.

TABLE 6

LAMP 7

Angle	Test 1	Test 2	Test 3
60° A			113.7
50	49.9	104.9	145 8
40	65.6	135.2	157.6
30	103.3	164.7	183.7
20	150.2	167.9	194.2
10	135.4	231.7	218.7
Hor.	182.7	256.5	215.1
10 B	191.3	299.2	251.9
20	225.7	313.	242.5
30	237.4	357.6	234.9
40	236.8	407.9	238.6
50	195.6	403.5	234.2
60	173.4	235.	220.6
70	142.3	173.4	193.4
80	63.3	197.9	237.
Globes	**Op. Inner Coated. Clear Outer**	**Op. Inner Clear Outer**	**Op. Inner Op. Outer.**
E. M. F.	110 volts	110 volts	110 volts
Current	4.76 amperes	4.66 amperes	4.87 amperes
Watts	523.6	512.6	535.7
Mean hemispherical intensity, H. U.	Upper, 96. Lower, 200.	149. 316.8	175. 232.
Mean spherical, H. U.	148.	232.9	203.5
Watts per mean spherical, H. U.	3.54	2.20	2.63

Hence the power required to produce one unit of light in this type of lamp is

Opalescent inner, no outer* =2.10 watts.
" " clear outer =2.66 watts.
" " opalescent outer =3.04 watts.

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*The computations for no outer globe have not the same value as the others, for the reason that the number of such tests was less.

In conclusion, I would call attention to the fact that these figures give the value of this type of lamp

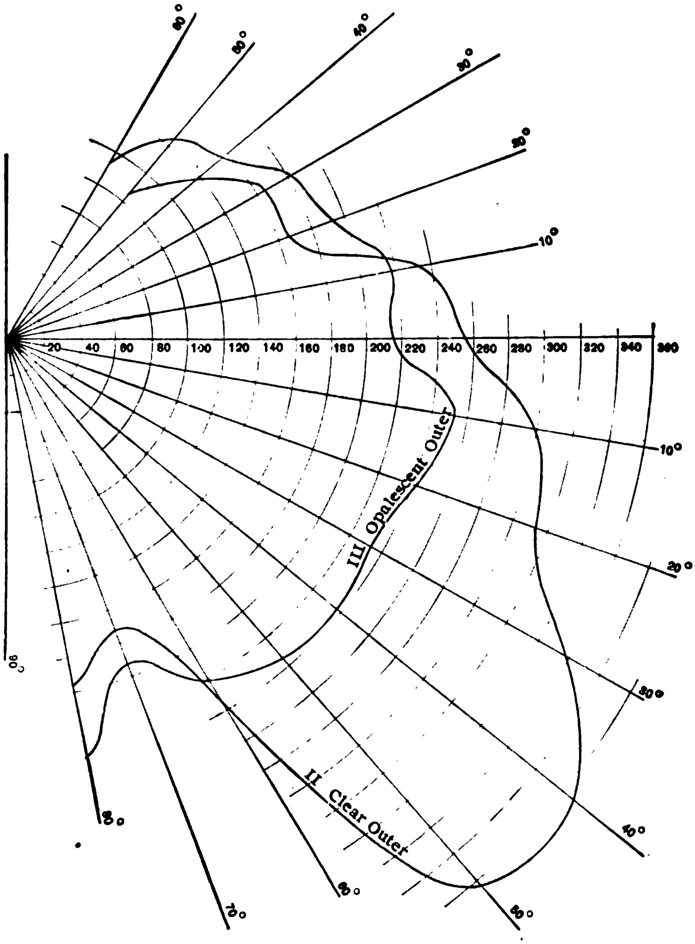

FIG. 12.—LAMP 7.
Curve II.—Clear Outer Globe. Curve III.—Opalescent Outer Globe.

as a *light producer*, and not as a *light distributor*. The efficiency of the type as a distributor of light can best be found from a consideration of the curves of illumination—a matter that does not form a part of this investigation.

SECOND INVESTIGATION

As furnishing data on the luminous intensity, power consumption and efficiency of the alternating-current, inclosed arc lamp for constant-potential circuits, I give below the results of tests on seven lamps. These tests have been carried through under conditions identical with those prevailing in the first investigation. In two cases the lamps were accom-

TABLE 7

LAMP 9

Angle	Test 1	Test 2
55° A	126.5	91.8
50	153.6	118.0
40	189.1	168.7
30	188.4	184.1
20	211.5	243.5
10	211.3	220.2
Hor.	209.4	247.6
10 B	231.4	323.9
20	206.9	301.6
30	217.0	313.3
40	181.4	294.0
50	158.0	253.5
60	165.5	214.1
70	136.5	254.7
80	156.4	110.
Globes	Op. Inner Op. Outer	Op. Inner Clear Outer
E. M. F.	110 volts	110 volts
Current	4.79 amperes	4.9 amperes
Watts	526.9	539.
Mean hemispherical intensity, H. U.	Upper, 170.4 Lower, 194.4	171.2 281.2
Mean spherical, H. U.	182.4	226.2
Watts per mean spherical H. U.	2.83	2.38

panied by shades, and these lamps were subjected to additional tests to bring out the advantages of using a shade on an alternating-current lamp.

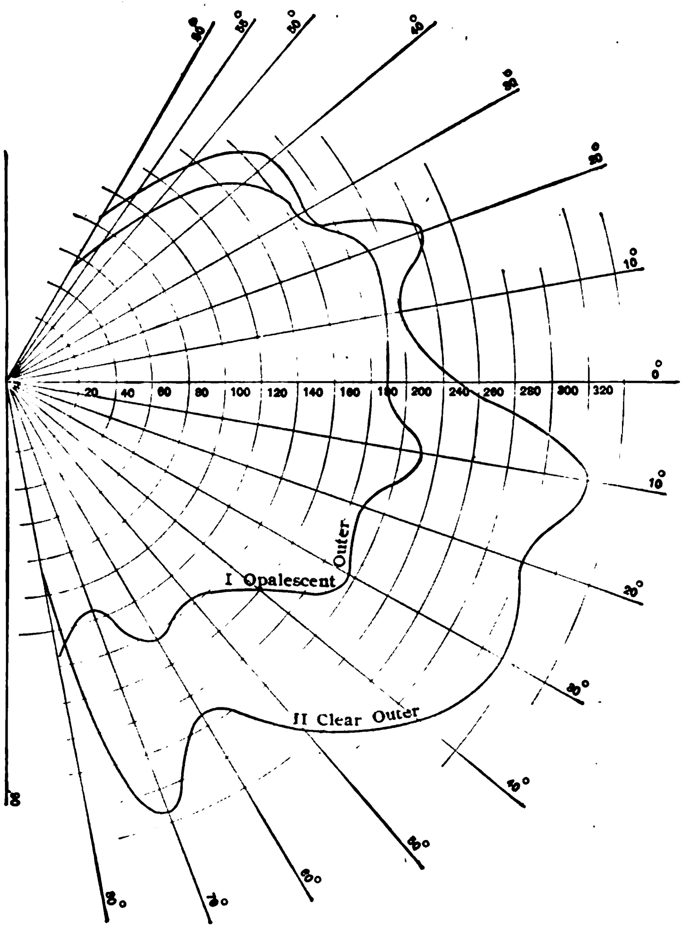

FIG. 13.—LAMP 9.

Curve I.—Opalescent Outer Globe. Curve II.—Clear Outer Globe.

The lamps are adjusted for voltage at the arc, and for the frequency of the supply, which is 60 cycles.

After burning a sufficient time, they are tested in the manner already described.

Since lamps of this type are used with one cored and one solid carbon, some difference in the curve of distribution might be looked for as a result of using the cored carbon above and the solid one below, or vice versa. In Table 11 and Figure 16 will be found the results of two tests intended to give information on this point. Lamp 102 was tested under the usual conditions of an opalescent inner and a clear outer globe, the cored carbon being below. Some days

TABLE 8

Lamp 10

Angle	Test 1	Test 2
59°A	(55A) 110.1	
50	125.7	82.7
40	129.7	177.7
30	188.1	198.7
20	219.6	230.
10	264.1	268.2
Hor.	246.8	247.
10 B	239.6	279.7
20	230.7	370.7
30	293.6	399.2
40	244.1	353.5
50	210.7	254.2
60	215.9	277.7
70	135.9	279.2
80	154.	121.5

Globes	Op. Inner Op. Outer	Op. Inner Clear Outer
E. M. F.	110 volts	110 volts
Current	5.05 amperes	4.94 amperes
Watts	555.5	543.4
Mean hemispherical intensity, H. U.	Upper, 173.6 Lower, 230.8	176. 308.8
Mean spherical H. U.	202.2	242.4
Watts per mean spherical H. U.	2.74	2.24

later the lamp was tested with the same globes, but with the carbon pencils interchanged, the upper pencil

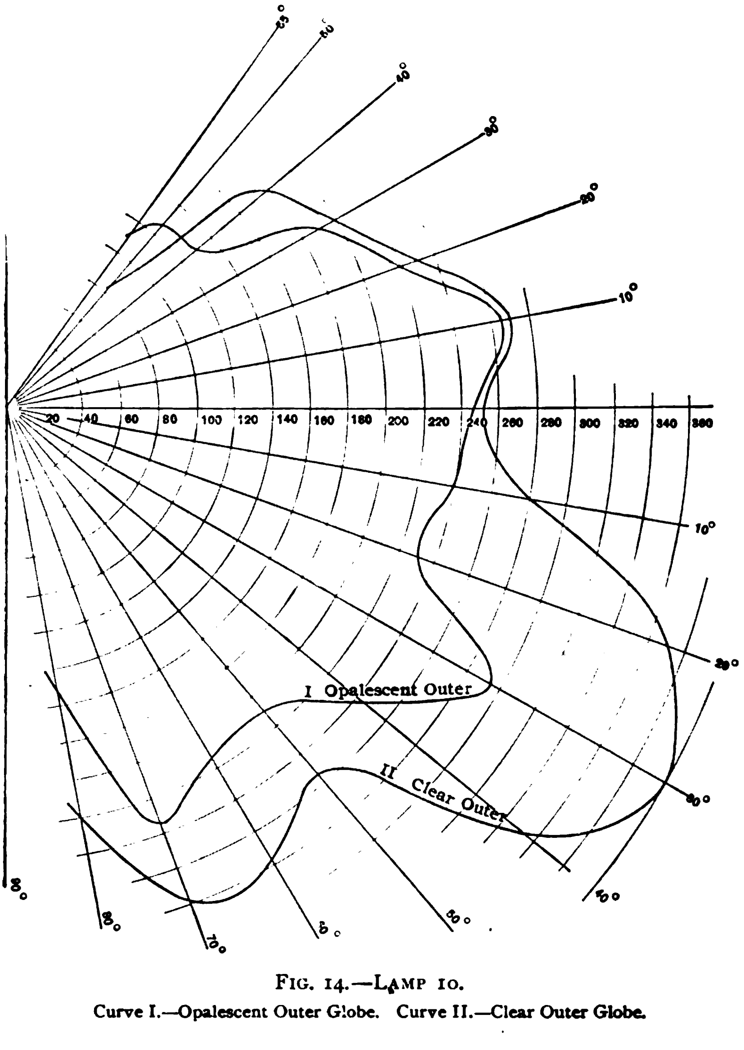

FIG. 14.—LAMP 10.
Curve I.—Opalescent Outer Globe. Curve II.—Clear Outer Globe.

being the cored one. The globe was clean in both cases. It will be noted that the curves follow each other closely, particularly below the horizontal. The slight variations in the curves neutralize each other so that the mean spherical intensity comes out the same in both cases. It is to be concluded from this test that the reversal of the carbons, which takes place whenever the lamp is newly trimmed, makes but little difference in the total luminous flux from the lamp. However, in the tests reported below, the uniform practice of a cored lower carbon was kept to.

TABLE 9

LAMP 12

Angle	Test 2	Test 4	Test 5
54° A	116.9		
50	134.8	61.1	78.4
40	169.8	126.9	129.2
30	171.2	211.9	138.4
20	176.4	236.3	154.2
10	190.9	253.0	162.3
Hor.	219.8	239.9	186.1
10 B	228.0	247.8	241.9
20	214.8	282.3	236.3
30	198.3	269.8	208.2
40	189.1	236.7	209.2
50	175.0	195.3	185.1
60	171.9	173.2	151.5
70	137.9	168.4	176.7
80	251.5	84.0	150.3
Globes	Op. Inner Op. Outer	Op. Inner Clear Outer	Op. Inner Coated. Clear Outer
E. M. F.	110 volts	110 volts	110 volts
Current	4.93 amperes	4.73 amperes	4.74 amperes
Watts	542.3	520.3	521.4
Mean hemispherical intensity, H. U.	Upper, 154.4 Lower, 200.8	160. 230.4	120.8 204.8
Mean spherical H. U.	177.6	195.2	162.8
Watts per mean spherical H. U.	3.05	2.66	3.20

Table 12 and Figure 17 exhibit the results of a test on lamp 101. These might be taken for the curves from a direct-current lamp, so small is the luminous flux in the upper hemisphere. It must be

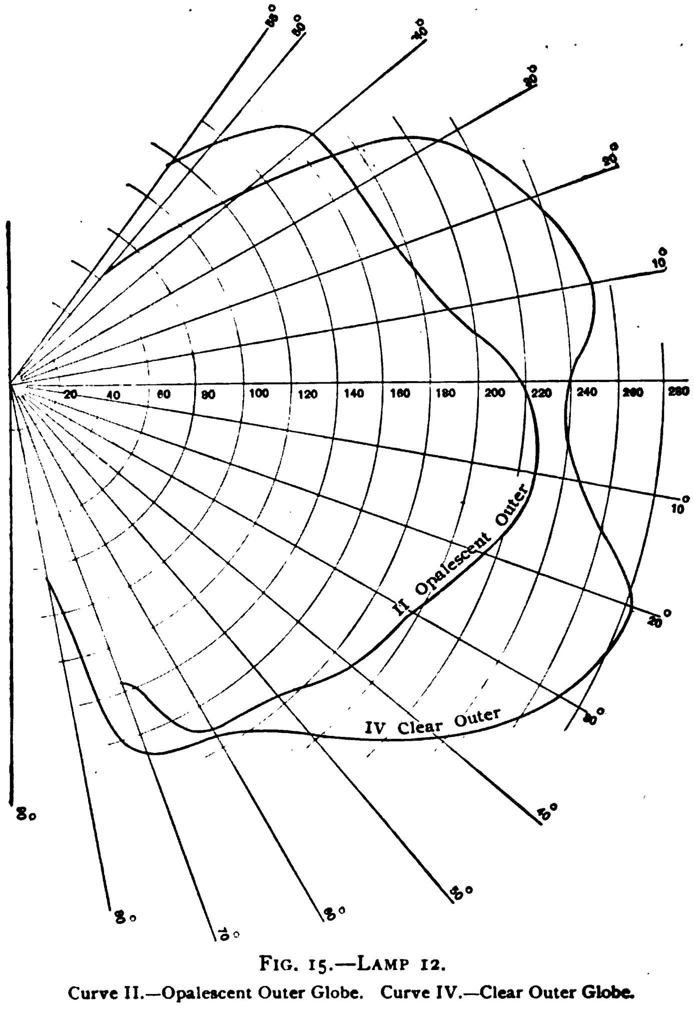

FIG. 15.—LAMP 12.
Curve II.—Opalescent Outer Globe. Curve IV.—Clear Outer Globe.

remembered, however, that the arc is at the top of the globe, as already explained, and much of the upward light is either absorbed or reflected by the comparatively broad surfaces just above the inner globe.

The maximum intensity is found in its usual position, thirty degrees below. The opalescent outer globe shows the usual diffusive properties.

TABLE 10

LAMP 12

Angle	Test 1	Test 3
54°A	76.9	
50	77.7	72.6
40	123.2	163.0
30	140.9	228.9
20	150.8	259.
10	155.1	276.6
Hor.	169.8	314.1
10 B	165.1	343.9
20	166.7	314.1
30	195.6	300.8
40	167.8	255.3
50	175.9	258.3
60	176.2	207.8
70	210.3	87.3
80	169.6	197.2
Globes	**Op. Inner Coated. Clear Outer**	**Op. Inner Clear Outer**
E. M. F.	110 volts	110 volts
Current	4.98 amperes	4.97 amperes
Watts	547.8	546.7
Mean hemispherical intensity, H. U.	Upper, 125.4 Lower, 176.8	185.6 281.2
Mean spherical H. U.	151.1	233.4
Watts per mean spherical H. U.	3.62	2.34

Three tests on lamp 102 have been carried out. The highly beneficial effect of a shade is here well shown. (Figure 18.) With the arc at the top of the globe, the shade in this case received all the upward flux of light and a portion of the downward flux. The result is that the horizontal intensity is diminished, but below ten degrees B the result of substituting a shade for an outer globe is very

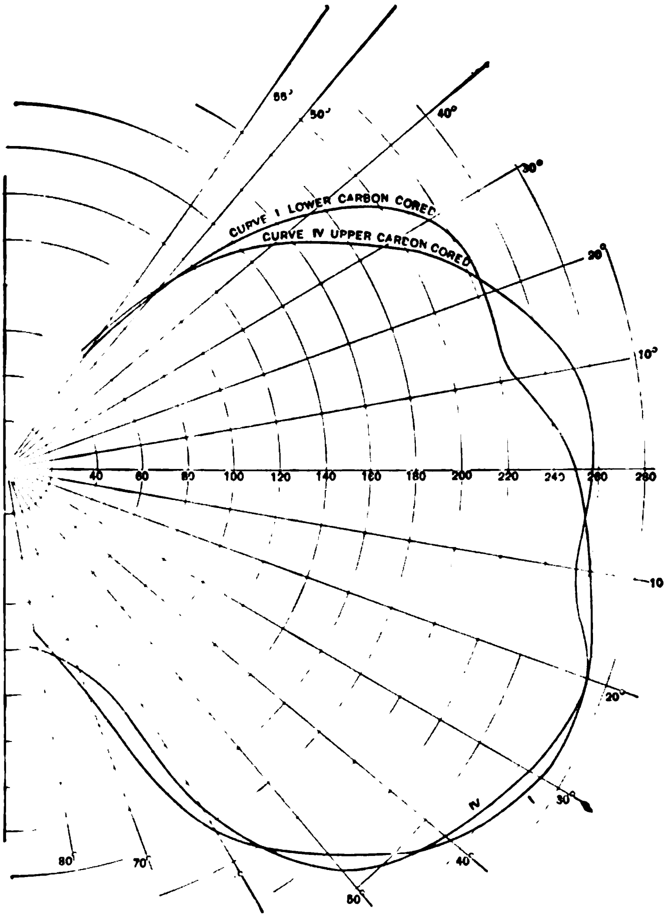

FIG. 16.—LAMP 102.

Curve I.—Clear Outer, Lower Carbon Cored. Curve IV.—Clear Outer, Upper Carbon Cored.

beneficial. In fact, the mean hemispherical intensity with shade bears to that with clear outer globe the ratio 266 : 236, or an increase of nearly thirteen per cent. Taking a similar ratio with reference to the opalescent outer globe, one finds 266 : 165, or an increase of sixty-one per cent. As the arc burns lower, the intensities between the horizontal and ten degrees B will naturally be strengthened, because the arc will no longer be eclipsed by the shade. At the same time the intensities in all directions will be increased, for the reasons already discussed in connection with Figure 7. For the illumination of points remote from the arc it is better that the solid

TABLE 11

Angle	Test 1	Test 4
55°A	66.1	57.3
50	96.1	97.3
40	170.9	152.2
30	215.7	195.3
20	223.6	227.5
10	225.9	252.2
Hor.	249.8	256.0
10 B	259.8	253.3
20	270.4	270.8
30	270.7	265.2
40	256.5	251.9
50	220.8	229.7
60	184.8	174.0
70	106.1	93.8
80	72.6	81.4
Globes	Op. Inner Clear Outer	Op. Inner Clear Outer
E. M. F.	110 volts	110 volts
Current	6.81 amperes	6.80 amperes
App. Watts	749.1	748.
Watts	459.	478.
Power Factor	.61	.63
Mean hemispherical intensity in H. U	Upper, 169.4 Lower, 236.5	169.4 234.6
Mean spherical in H. U.	202.9	202.
Watts per mean H. U.	2.26	2.36

angle subtended by the shade should not exceed 2π steradians, as it does in the case here represented.

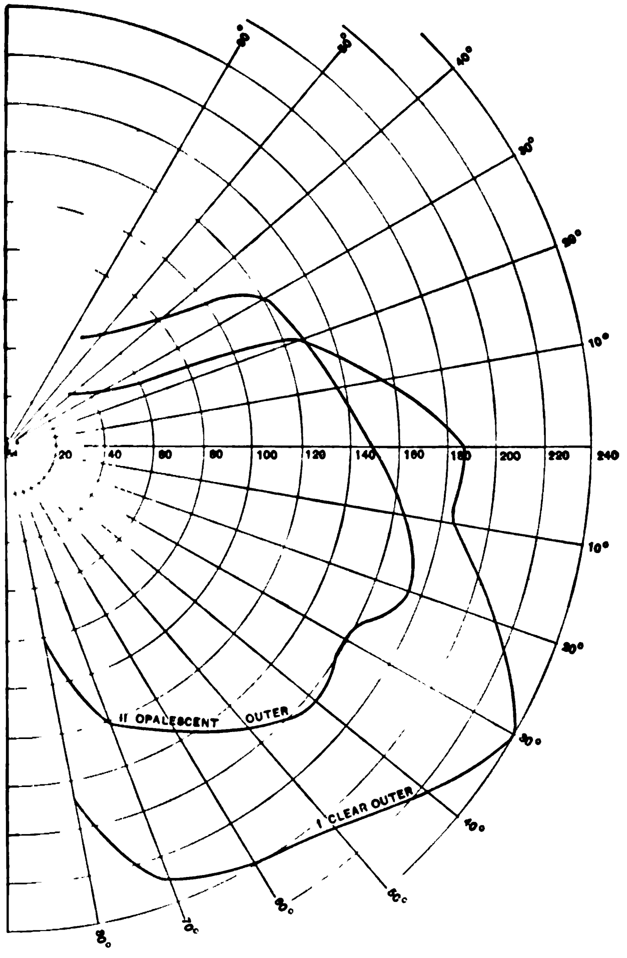

FIG. 17.—LAMP 101.

Curve I.—Clear Outer Globe. Curve II.—Opalescent Outer Globe.

It will further be noted that there is an abundance of light at all points beneath the lamp, both with shade and with opalescent outer globe.

Figure 19 (see Table 14) shows the results on a lamp fitted with an inner globe having straight side walls. The curve is very strong in the horizontal and falls off at all angles, both above and below.

TABLE 12

LAMP 101

Angle	Test 1	Test 2
55°A		54.2
50		58.6
40	33.5	79.4
30	42.4	122.
20	127.0	128.7
10	154.3	137.4
Hor.	185.0	149.2
10 B	186.2	165.2
20	213.0	175.7
30	239.3	160.0
40	223.1	164.7
50	206.8	152.9
60	200.0	137.6
70	191.0	123.0
80	149.8	82.8
Globes	Op. Inner Clear Outer	Op. Inner Op. Outer
E. M. F.	110 volts	110 volts
Current	6.47 amperes	6.34 amperes
Watts app.	711.7	697.4
Watts	448.	446.
Power factor	.62	.63
Mean hemispherical intensity, H. U.	Upper, 76.7 Lower, 205.6	97.5 156.
Mean spherical, H. U.	141.1	126.7
Watts per mean spherical, H. U.	3.17	3.52

Whether or not this effect is associated with the shape of this type of globe, I dare not say without further investigation, but the matter can be settled definitely when the tests on inner globes of different shapes are carried out.

Another lamp having a shade is 106. (Table 16, Figure 21.) The shade in this case extends downward

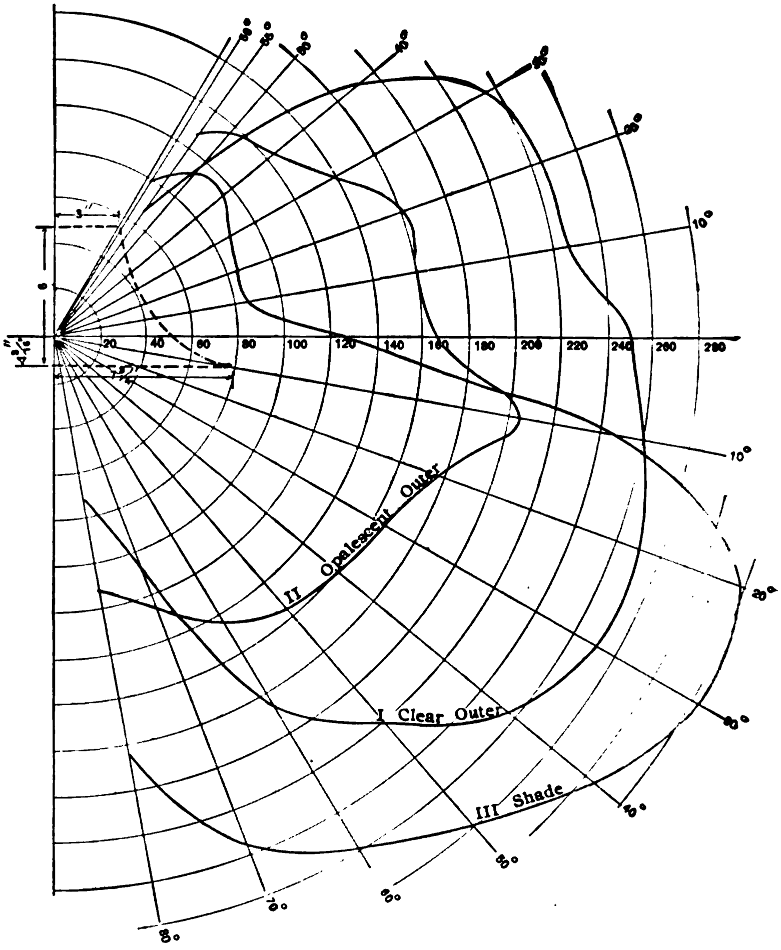

Fig. 18.—Lamp 102.

Curve I.—Clear Outer Globe. Curve II.—Opalescent Outer Globe. Curve III.—Shade.

to a plane about a half-inch above the arc, when the latter is at its highest point. The horizontal intensity with shade is slightly less than with clear outer globe, showing that the latter strengthens this intensity by diffusion more than it reduces by absorption. The increase in intensity from the horizontal to twenty degrees B is very marked when the shade is employed

TABLE 13

Lamp 102

Angle	Test 1	Test 2	Test 3
59°A			77.6
55	66.1	106.6	
50	96.1	116.7	94.6
40	170.9	123.9	95.0
30	215.7	139.9	86.8
20	223.6	160.7	84.2
10	225.9	159.6	86.1
Hor.	249.8	165.6	124.1
10 B	259.8	204.4	245.3
20	270.4	176.3	317.3
30	270.7	161.1	322.6
40	256.5	161.1	304.6
50	220.8	154.3	280.2
60	184.8	144.8	258.6
70	106.1	125.5	236.6
80	72.6	112.6	186.7

Globes	Op. Inner Clear Outer	Op. Inner Op. Outer	Op. Inner Shade
E. M. F.	110 volts	110 volts	110 volts
Current	6.81 amperes	6.78 amperes	6.77 amperes
App. watts	749.1	745.8	744.7
Watts	459.	483.	457.
Power factor	.61	.64	.61
Mean hemispherical intensity in H. U.	Upper, 169.4	127.2	85.2
	Lower, 236.5	164.8	266.4
Mean spherical in H. U.	202.9	146.	175.8
Watts per mean spherical in H. U.	2.26	3.31	2.60

in the position here indicated, and these are angles of most importance in street lighting, if not in interiors. The mean hemispherical intensity is altered by the substitution of the shade for the clear outer globe in the ratio of 254:169 or fifty per cent as against thirteen per cent in the case of lamp 102. It is worth noting that the curvature of the two shades is

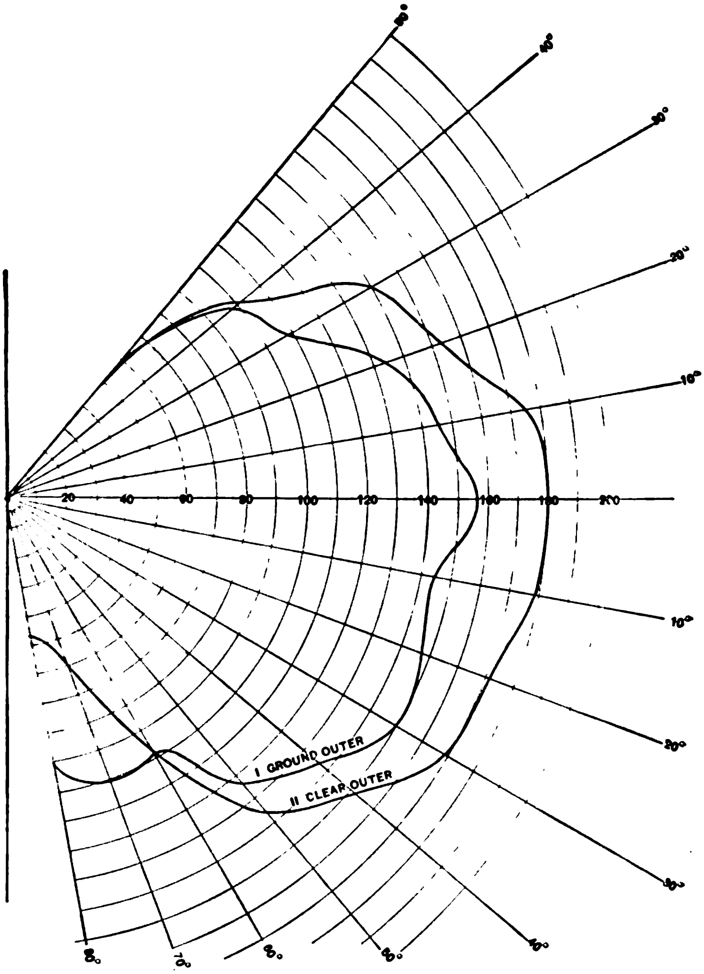

Fig. 19.—Lamp 103.

Curve I.—Ground Outer Globe. Curve II.—Clear Outer Globe.

opposite—that of 106 being such as to reflect light incident at high angles, so as to make it useful, while that of 102 throws light incident at angles higher than about twenty-five degrees A upwards, where it is, in a large measure, dissipated by multiple reflection and absorption. This fact accounts, I think, for the great difference in these two examples of the employment of a shade. The low, flat shade, concave inwards, is certainly superior optically, if not artistically.

TABLE 14

Lamp 103

Angle	Test 1	Test 2
50°A	59.8	50.7
40	98.0	101.6
30	108.0	140.3
20	133.6	153.9
10	145.8	174.7
Hor.	156.9	180.2
10 B	145.1	179.2
20	147.4	172.2
30	150.3	169.1
40	136.5	152.3
50	123.6	136 5
60	99.4	96.0
70	101.0	59.8
80	89.9	47.3
Globes	**Op. Inner Ground Outer**	**Op. Inner Clear Outer**
E. M. F.	110 volts	110 volts
Current	5.91 amperes	5.87 amperes
App. watts	650.1	645.7
Watts	424.	410.
Power factor	.65	.63
Mean hemispherical intensity in H. U.	Upper, 98.2 Lower, 133.2	113. 146.8
Mean spherical in H. U.	115.7	129.9
Watts per mean spherical, H. U.	3.66	3.15

As to the efficiency of this type of lamp, we have in Table 19 a recapitulation of the power measurements in the alternating-current lamps. The mean power consumption of seven lamps is 417 watts. The average value of the mean spherical intensity is:

With clear outer globe,	159	H. U.
" opalescent outer globe,	130	H. U.

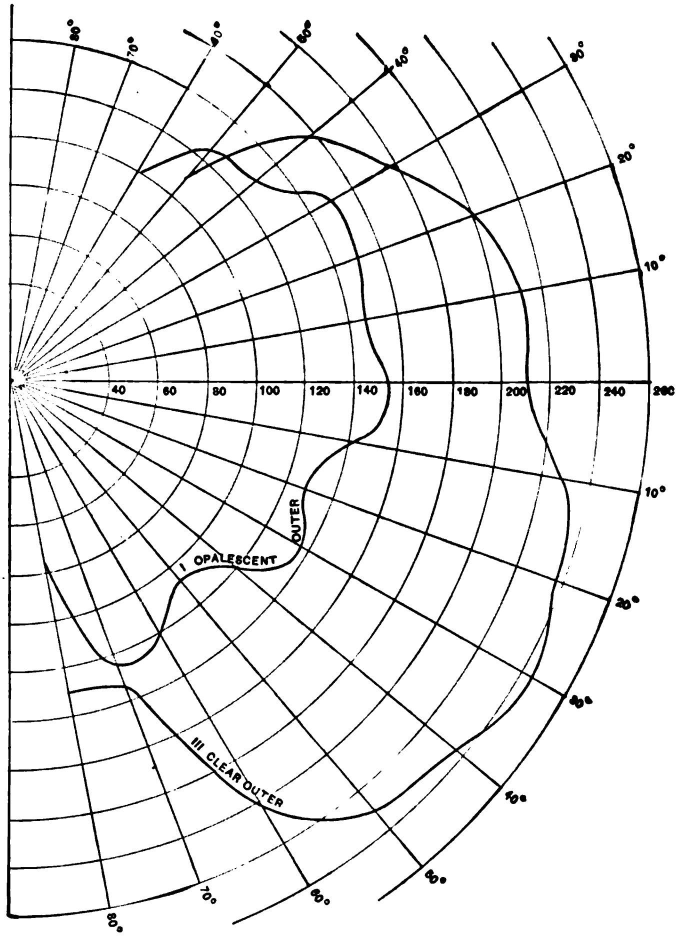

FIG. 20.—LAMP 105.
Curve I.—Opalescent Outer Globe. Curve III.—Clear Outer Globe.

Therefore, as light producers, the average efficiency is:

With clear outer globe, 2.62
" opalescent outer globe, 3.21

in watts per mean spherical Hefner unit. The mean power in the arc is 342 watts, and in the mechanism 74 watts.

TABLE 15

LAMP 105

Angle	Test 1	Test 3
59°A	99.9	
55		
50	124.0	109.3
40	129.0	157.8
30	149.1	177.1
20	150.4	205.7
10	146.3	211.2
Hor.	153.4	211.2
10 B	142.2	228.3
20	128.1	236.6
30	137.6	244.6
40	121.0	236.1
50	107.0	231.1
60	120.6	202.9
70	125.1	134.9
80	77.0	131.1

Globes	Op. Inner Op. Outer	Op. Inner Clear Outer
E. M. F.	110 volts	110 volts
Current	6.21 amperes	6.19 amperes
App. watts	683.1	680.9
Watts	414.	410.
Power factor	.60	.60
Mean hemispherical intensity in H. U.	Upper, 128.4 Lower, 127.3	154.8 218.8
Mean spherical in H. U.	127.8	186.8
Watts per mean spherical in H. U.	3.24	2.20

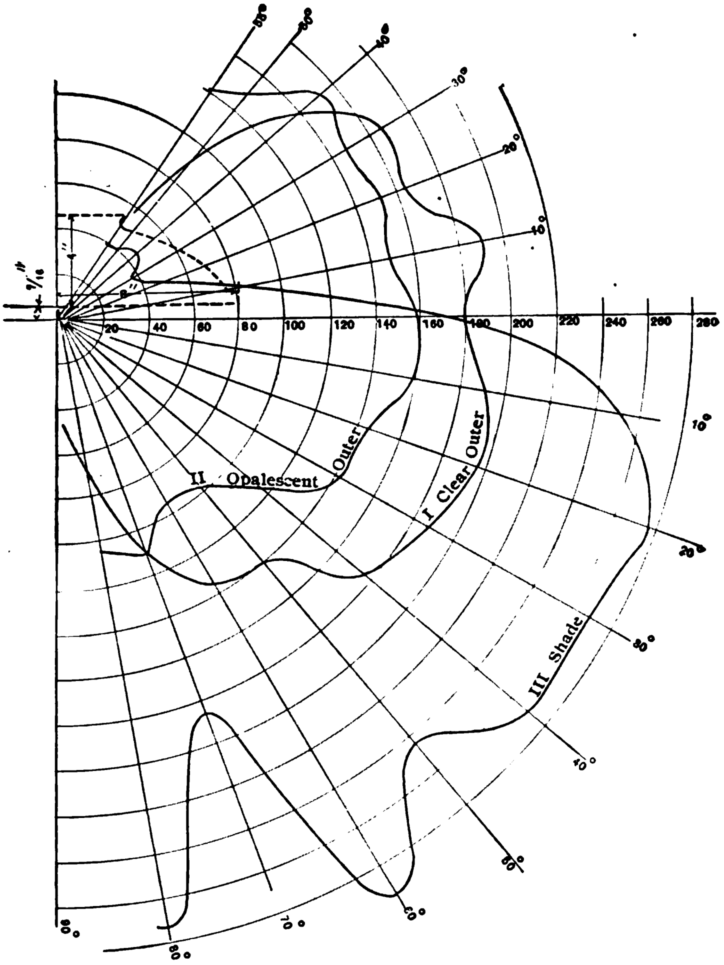

FIG. 21.—LAMP 106.

Curve I.—Clear Outer Globe. Curve II.—Opalescent Outer Globe. Curve III.—Shade.

TABLE 16

Lamp 106

Angle	Test 1	Test 2	Test 3
55°A	59.9	39.5	122.9
50	90.8	40.1	129.2
40	139.1	44.0	152.4
30	164.9	36.8	147.3
20	163.7	46.7	152.6
10	189.7	79.0	149.4
Hor.	179.9	174.9	159.0
10 B	191.9	251.9	158.4
20	196.4	276.2	145.7
30	188.0	268.4	143.3
40	177.7	269.1	117.2
50	140.7	244.8	98.2
60	136.5	293.6	95.2
70	108.1	186.6	109.9
80	63.4	272.5	103.8

Globes	Op. Inner Clear Outer	Op. Inner Shade	Op. Inner Op. Outer
E. M. F.	110 volts	110 volts	110 volts
Current	6.1 amperes	6.1 amperes	6.17 amperes
App. watts	671.	671.	678.7
Watts	392.	378.	371.
Power Factor	.58	.56	.54
Mean hemispherical intensity in H. U.	Upper, 136.8 Lower, 169.5	49.6 254.4	132.8 130.4
Mean spherical in H. U.	153.1	152.	131.6
Watts per mean spherical in H. U.	2.56	2.49	2.82

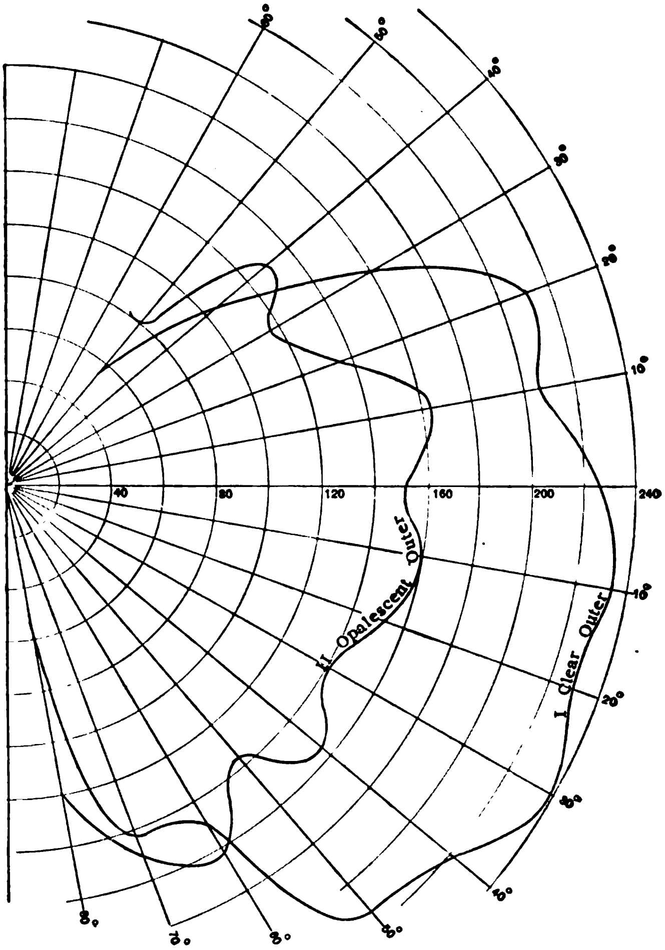

FIG. 22.—LAMP 108.

Curve I.—Clear Outer Globe. Curve II.—Opalescent Outer Globe.

TABLE 17

Lamp 108

Angle	Test 1	Test 2	Test 3
55°A		82.9	52.2
50	55.8	80.9	111.2
40	105.1	130.7	186.6
30	159.0	116.5	216.1
20	210.7	134.5	220.5
10	206.0	163.3	217.9
Hor.	225.1	151.9	183.2
10 B	234.4	160.5	219.0
20	229.4	153.3	249.2
30	239.1	142.9	279.1
40	222.6	156.7	279.3
50	215.8	137.7	224.4
60	150.2	162.9	204.7
70	143.0	150.9	231.7
80	52.6	121.1	151.2

Globes	Op. Inner Clear Outer	Op. Inner Op. Outer	Op. Inner Coated. Clear Outer
E. M. F.	110 volts	110 volts	110 volts
Current	6.56 amperes	6.47 amperes	6.41 amperes
App. watts	721 6	711.7	705.1
Watts	457.5	440.	462.
Power factor	.63	.61	.65
Mean hemispherical intensity in H. U.	Upper, 139.9 Lower, 211.2	115.9 150.4	167.5 233.7
Mean spherical, H. U.	175.5	133.1	200.6
Watts per mean spherical, H. U.	2.61	3.30	2.30

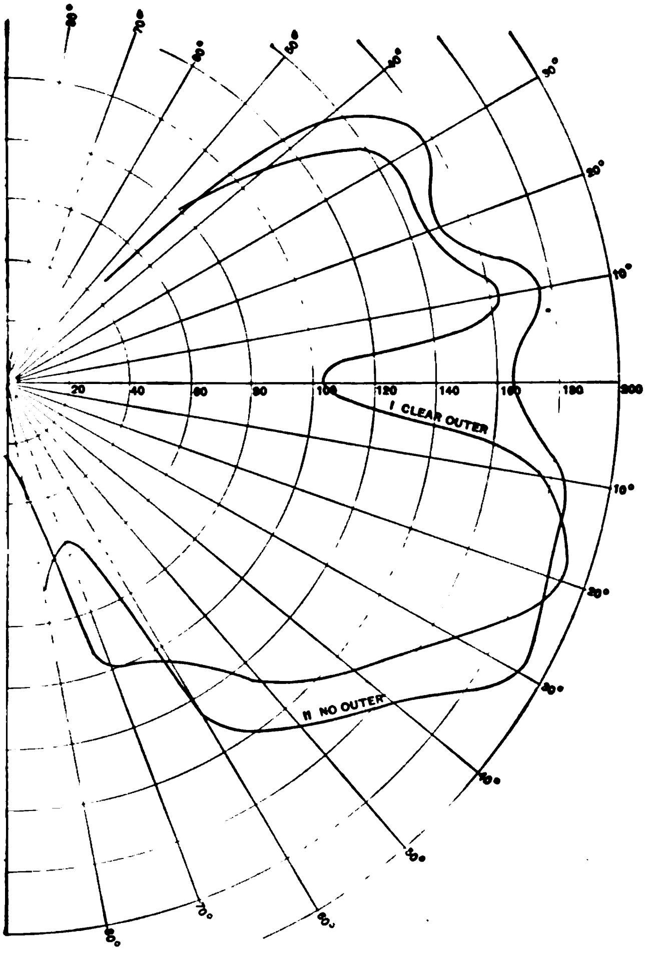

FIG. 23.—LAMP 110.
Curve I.—Clear Outer Globe. Curve II.—No Outer Globe.

TABLE 18

LAMP 110

Angle	Test 1	Test 2
45°A	80.4	66.4
40	106.6	132.9
30	144.2	157.2
20	146.2	149.4
10	162.6	176.4
Hor.	103.3	165.2
10 B	176.2	184.7
20	192.8	187.6
30	168.7	192.0
40	147.2	164.7
50	128.7	148.4
60	105.5	126.3
70	98.6	55.3
80	36.5	70.4

Globes	Op. Inner Clear Outer	Op. Inner No Outer
E. M. F.	110 volts	110 volts
Current	6.07 amperes	6.3 amperes
App. watts	667.7	693.
Watts	339.	338.
Power factor	.50	.48
Mean hemispherical intensity in H. U.	Upper, 109.6 Lower, 143.2	118.4 161.6
Mean spherical in H. U.	126.4	140.
Watts per mean spherical in H. U.	2.68	2.41

TABLE 19

POWER MEASUREMENTS

	Total	In Arc	Mechanism
Lamp No. 101	448	340	108
" " 102	459	375	84
" " 103	424	344	80
" " 105	414	382	32
" " 106	378	298	80
" " 108	457	383	74
" " 110	339	276	63

THIRD—A REPORT ON THE RELATIVE VALUE OF DIRECT AND ALTERNATING-CURRENT LAMPS.

The lamps used in the two foregoing investigations, considered as types, are unfortunately not of the same power consumption, but regarding them merely as light producers, the average direct-current lamp yields, with opalescent inner and a clear outer globe, 207 h. u., whereas the average alternating-current lamp for circuits of the same pressure yields 159 h. u., which gives the former lamp an advantage as a light source, irrespective of efficiency, in the ratio of 48:159 or thirty per cent. It is pretty well demonstrated that the alternating arc is *per se* less efficient than the direct-current arc. Just what the proper ratio may be is a matter for physical research, and varies with several factors, such as current density, wave form, character of the circuit, etc. We have no data in these investigations to furnish reliable information on this point, as there are too many variable conditions met in the lamps as found in their commercial form.

Comparing the average performance of the lamps in the first series of tests with the average performance of the lamps in the second series of tests, one finds very nearly the same power consumption per light unit, namely:

	D. C.	A. C.
Clear outer	2.60	2.62
Opalescent outer	3.04	3.21

This result differs from one that I have formerly published, which shows the direct-current lamp, as a result of a *single* comparison as superior in economy to the other type. I consider the combined result of these tests as of far greater value than the result of the single comparison. Moreover, a considerable improvement in the alternating-current lamp has doubtless taken place in the last two years, whereby its economy, as well as its operation, are found to be bettered.

Question of design, steadiness of operation, carbon consumption, etc., are purposely left out of this comparison until such time as more data shall be available.

To compare the direct-current lamp with the alternating-current lamp on the basis of mean spherical intensity is not always fair. When a diffusing outer globe is used, this basis of comparison is correct enough, for the reason that the distribution of intensity is fairly constant in all directions, both for the direct and alternating-current types.

For outdoor use, however, lamps will be provided with inner globes only, or clear outer globes, or shades, as the case may be. In any event, the upward luminous flux which passes the globes or shades is practically of no utility. Hence for outdoor use the mean hemispherical intensity below a plane passing through the arc is a better basis for comparison.

Now, the average direct-current lamp in this series of tests yields a mean hemispherical intensity of 273 h. u. with clear outer globe. The average alternating-current lamp yields but 190 h. u. This gives the former an advantage as a useful light source represented by the ratio of 83:190, or 43.7 per cent. Moreover, the power required per unit intensity is in the two cases 1.97 watts and 2.19 watts per mean hemispherical h. u., so that not only does the direct-current lamp with clear outer globe give a stronger mean intensity below the arc, but it does so at a higher efficiency. But it is wasteful to use an alternating-current lamp for street lighting without a shade or reflector. The tests on lamps 102 and 106 enable one to draw certain interesting comparisons. They give mean hemispherical intensities respectively of 266 and 254 h. u., or very nearly the same as the average direct-current lamp with clear outer. This yield is obtained at a power consumption of only 418 watts, which is 1.61 watts per h. u. This emphasizes the great importance of a shade on the alternating-current lamp. Finally, we may compare this last result with the performance of direct-current lamp 1, *with no outer globe* and no shade. Here the mean hemispherical intensity is 362 h. u., the power consumption 558 watts and the power per h. u. 1.54 watts. The conclusion, based on this single comparison, is that for street lighting the 550-watt (nominal rating) direct-current lamp without shade gives 39 per cent more useful light than the 450-watt (nominal rating) alternating-current lamp with shade and at slightly greater economy.

But the fact must not be lost sight of that this last comparison is between constant potential inclosed arcs as found on the market. The question of the light output and efficiency of the series alternating inclosed arc of the same power as the direct-current lamp will be taken up later.

Table 20 gives a summary of the results in the two foregoing investigations. I have also plotted (Figure 24) what may be termed a *composite* curve for each type. These curves are nothing more than means of the foregoing individual curves for a clear outer globe. The irregularities due to differences in globes, reflecting surfaces, and other causes are found to largely neutralize each other with the result of the smooth loci here shown. These two curves will be

TABLE 20.

D. C. Lamp.	Current.	Watts Consumed.					Mean Intensity in H. U.			Mean Watts.		
		In Lamp.		In Arc.		Mechanism.	Spherical.		Lower Hem-spherical.	Spherical H. U.		Lower Hem-spherical.
							Op. Outer	Clear Outer	Clear Outer	Op. Outer	Clear Outer	Clear Outer
1	5.01	551		401		150	172	235 256*	332 362*	3.10	2.37 2.18*	1.66 1.52*
3	5.08	559		406		152	195	216	282	2.85	2.60	1.99
4	4.76	524		381		143	127	139	208	4.12	3.76	2.52
5	4.16†	458		333		125	154	174	221	2.96	2.63	2.07
7	4.76	524		381		143	203	333	317	2.63	2.20	1.65
9	4.84	532		387		145	182	226	281	2.83	2.38	1.89
10	4.99	549		399		150	202	242	309	2.74	2.24	1.77
12	4.87	536		390		146	178	195	230	3.05	2.66	2.33
Mean	4.9	529		384		144	176	207	272	3.03	2.60	1.98
A. C. Lamp.			Power Factor Lamp.		Power Factor Arc.							
101	6.40	448	.63	340	.82	108	127	141	206	352	317	2.17
102	6.79	459	.61	375	.73	84	146	203 176†	236 266†	3.31	226 260†	1.94 1.72†
103	5.89	424	.65	344	.75	80	116	130	147	3.66	3.15	2.88
105	6.20	414	.61	382	.80	32	128	187	219	3.24	2.20	1.89
106	6.12	378	.56	298	.70	80	132	153 152†	169 254†	2.82	2.56 2.49†	2.23 1.48†
108	6.48	457	.64	383	.80	74.5	133	175	211	3.30	2.61	2.16
110	6.18	339	.49	276	.72	63	140*	126	143	2.41*	2.68	2.37
Mean	6.29	417	.60	342	.76	74.5	130	159	190	3.31	2.66	2.23

* Condition of no outer globe. † Condition with shade on Lamp.
NOTE—All marked values not included in the mean.

found valuable for the plotting of curves of illumination.

Absorption of Globes:

The results of the first and second investigations enable one to obtain some interesting figures on the absorption of the outer globes. It is evident that if we take the mean spherical intensity of any lamp with a clear outer globe, and divide it by the intensity obtained with no outer globe, we get a ratio that show the transmission of the clear globe. I am able to get this ratio in three cases. The values are 91.7, 90.3 and 88.8. The mean of these is 90.2. In other words, a clear globe cuts down the luminous flux from the inner globe by about ten per cent. In a

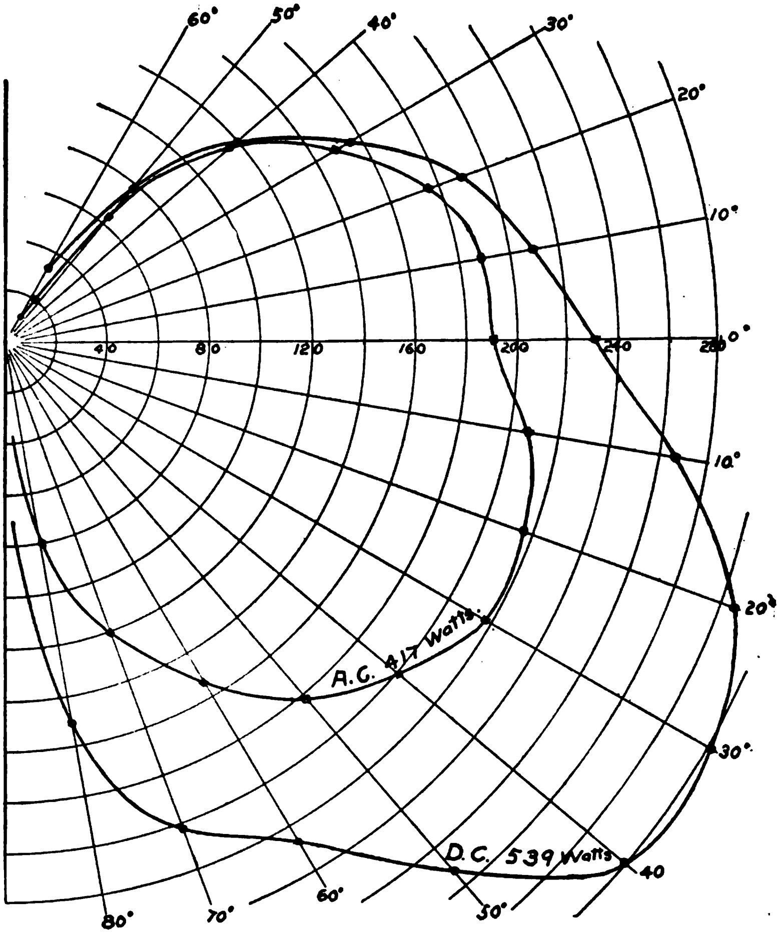

Fig. 24.

similar way two opalescent globes were found to produce an absorption of 21.8 and 32.4 per cent, or a mean of 27.1 per cent. These figures give what may be termed the absolute absorption of the clear and opalescent globes. We may also find the relative transmission (understanding the term transmission in a very general sense, that is to say, having in mind both diffusion and absorption) of the opalescent and clear outer globes by taking the ratio of the corresponding mean spherical intensities. Following are the values: 73.6, 90.3, 91.3, 88.9, 87.2, 80.7, 83.9, 91., 89.8, 72., 89.1, 69.4, 86., 75.8. The mean of the values is 83.5. It will be noted that there is a wide variation in these figures, the lowest being 69.4 and the highest 91.3. To look at the matter in another way, if we substract each one of these values from 100, we have a series of numbers that represent the diminution in mean spherical intensity resulting from the substitution of an opalescent globe for a clear globe in each case. The wide variations might have been predicted from a casual examination of the globes as sent by the manufacturers. Herein lies one large factor of uncertainty in determining the relative lighting value of different makes of inclosed arc lamps.

FOUR AND FIVE—INVESTIGATIONS ON THE COATING OF THE INNER GLOBE.

As regards the work called for under these headings, I am unable to do more at this date than to give the results of certain tests and experiments undertaken tentatively with a view of getting at the best method of procedure. Attention has already been called to the fact that the change in the intensity of an arc-lamp with the burning away of the carbons is due principally, if not entirely, to two factors, one of which is the coating formed on the inner globe. It becomes important to know the time-law of formation of this coating. To this end, several lamps, of both the direct and alternating-current types, were fitted with carbons and started on a time run. At intervals, the inner globes were removed and tested photometrically for absorption by placing inside of them a slender incandescent lamp maintained at constant intensity. It is not to be expected that the total absorption of such globes can be independent of the distribution of luminous intensity about the source within the globe. That is, the actual absorption with the glow lamp is likely to be different from that with the arc, yet the change in the absorption as the coating forms could not, it was thought, differ to any marked extent with the nature of the source. The results of these tests have not, as a rule, been very satisfactory, owing to a variety of complications which I need not here discuss. However, certain interesting points are made manifest from a consideration of the most uniform of these results. If we reduce the various intensities from the glow lamp at different angles to unity by dividing intensities in any given direction by the initial intensity in that direction, we have the effect of a source giving a uniform light in all directions. The falling of the intensities at different angles with time in the case of a direct-current lamp is shown in Figure 25, wherein the dotted lines represent the change in intensity at different angles, and the full curve the change in mean spherical intensity. The upper set of curves is for the angles above the horizontal; the lower set for the angles below the horizontal. The curves show clearly that the coating forms most heavily on the upper part of the globe, a fact which is apparent from the appearance of the globe. A fact which is not so apparent, but one which the curves bring out clearly, is that the coating forms very rapidly at first and then gradually decreases in rate of formation, or, to be more accurate, the absorption of light changes

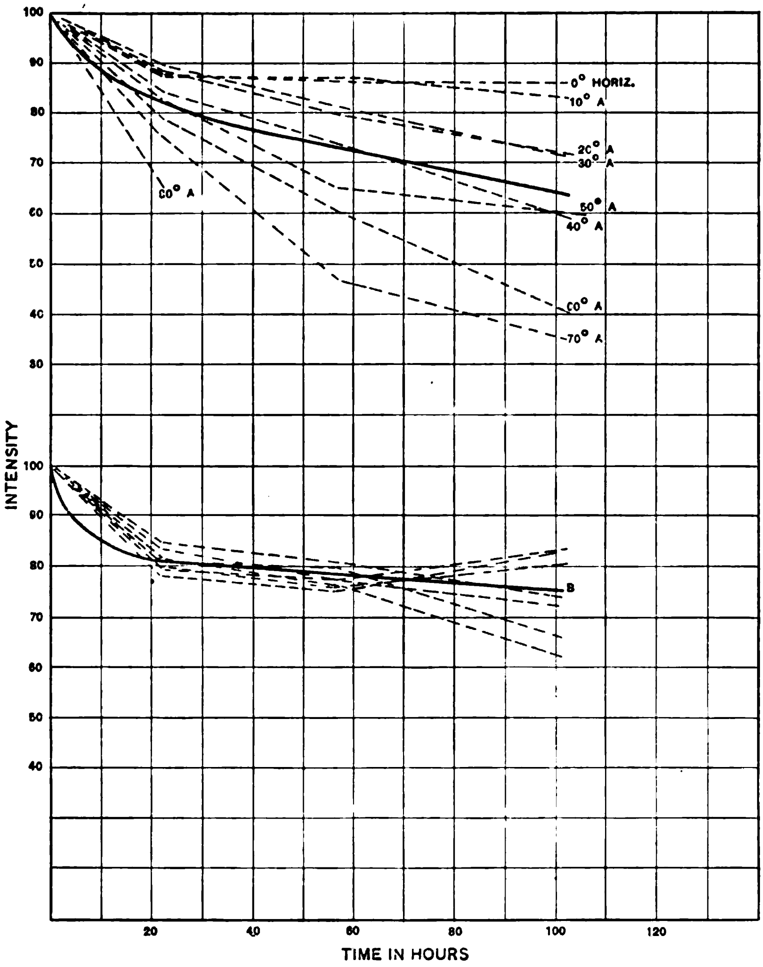

FIG. 25.

in this way. It will be noted that the mean hemispherical intensity falls from 100 to 64 in 100 hours.

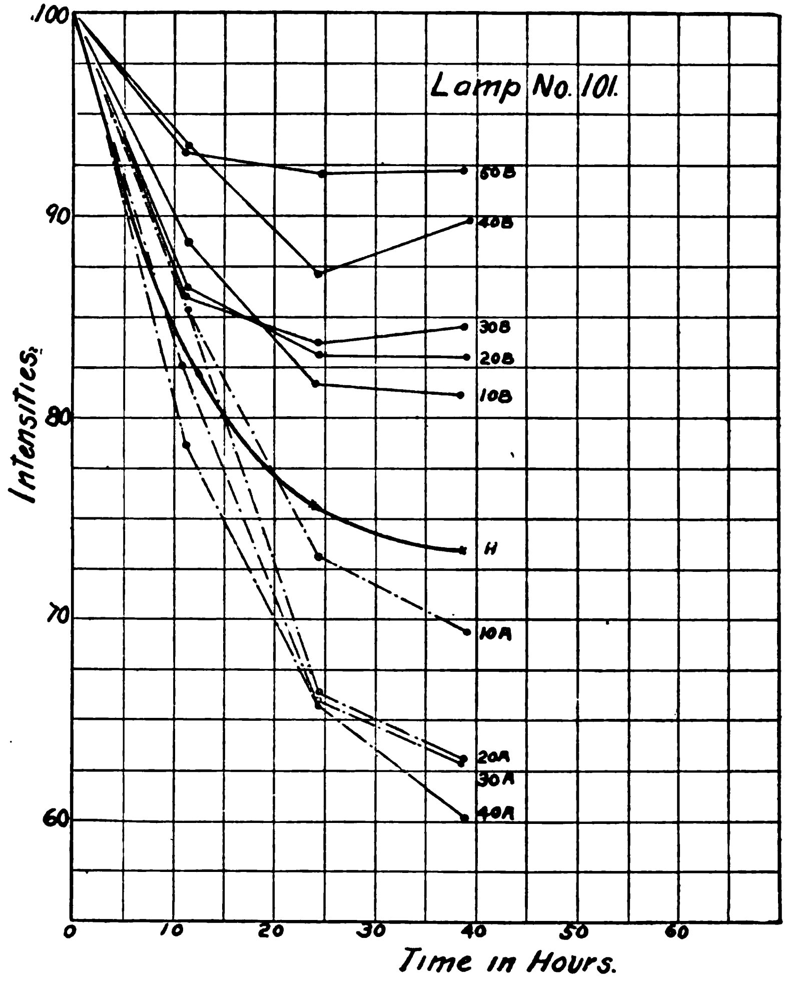

FIG. 26.

Below the horizontal, the falling off in the same time is from 100 to 76.

Figure 26 shows the formation of the coating in the case of an alternating lamp during a period of forty hours. Here again the coating forms most rapidly above the horizontal.

In the case of four alternating lamps the inner globes were weighed at intervals. When these weights are plotted against time we have the set of curves in Figure 27, extending from the origin upwards. Unlike

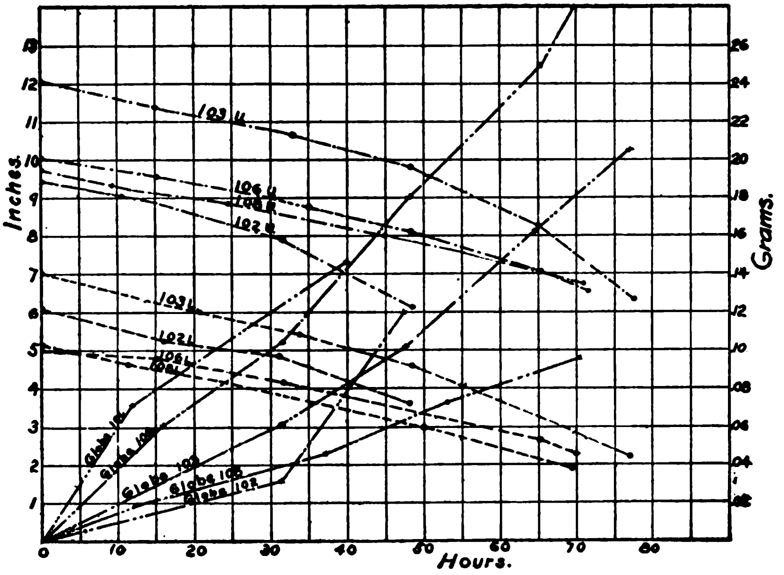

FIG. 27.

the absorption curves, these loci show an increasing rate of deposit with the life of the lamp. It is not to be expected that the increase in the mass of the deposit and in the amount of light cut off by the deposit should follow the same law. It seems reasonable that successive equal increments of coating might cut off diminishing increments of light, and the trend of the curves seems to indicate this clearly.

It was not intended to take up the matter of carbon life until a thorough study of the matter could be made apart from other things. However, as the weights of the carbons were taken at intervals during the runs made for the sake of the coating, I am able to plot certain curves of carbon consumption which

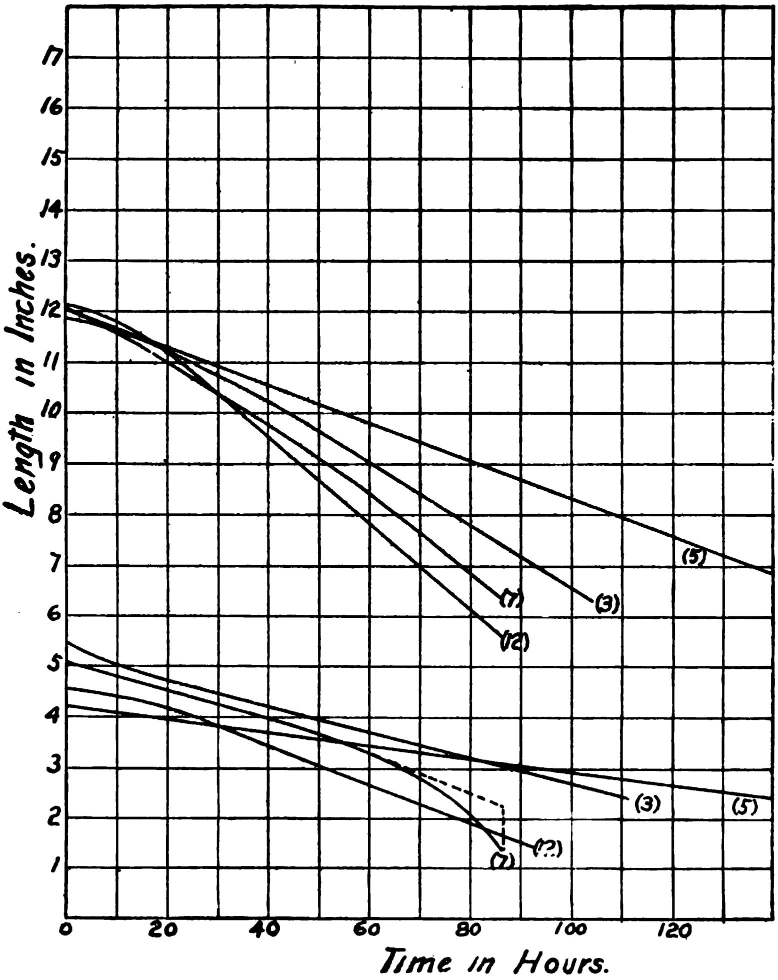

FIG. 28.

may be indicative of what may be found under a more extended investigation. The upper and lower carbon life curves of four alternating-current lamps

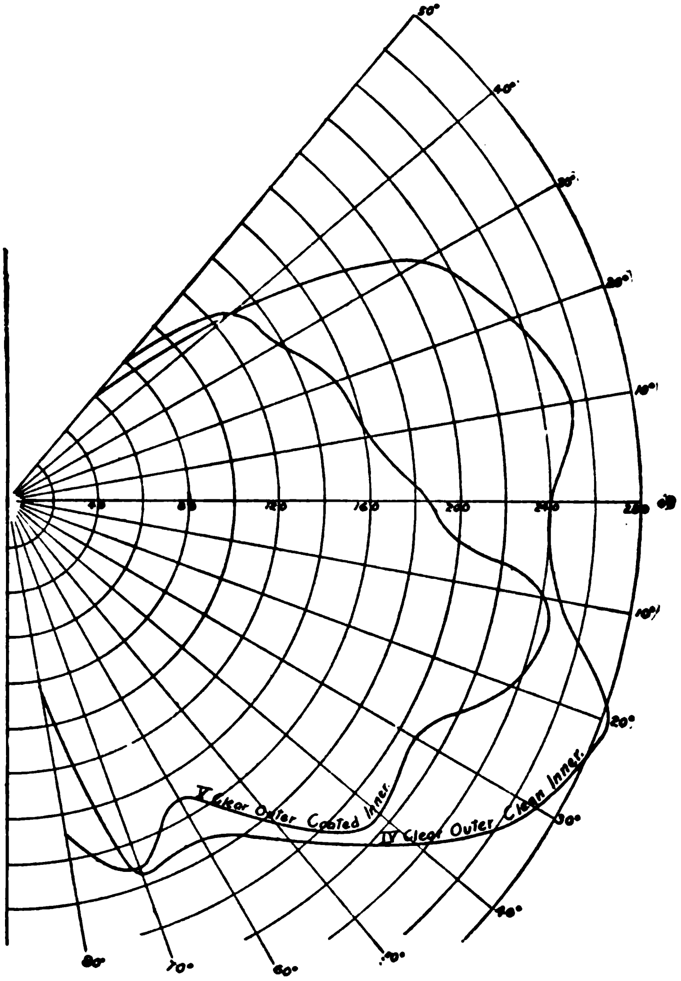

FIG. 29.

appear in Figure 27. There seems to be a tendency for the carbons to burn more rapidly towards the end of the life. This corresponds to the upward tendency to be noticed in all the weights of coating, except one. The life of the lamps, on one trimming, is in the vicinity of seventy hours. Lamp 102 cut out in 47.5 hours because of the rapid combustion of the upper carbon—the lower carbon being still quite long. There may have been some abnormal conditions in this case unknown to the observers.

Figure 28 shows a similar set of curves for four direct-current lamps. Lamp 7 failed to cut itself out and the bottom of the globe was fused. This accounts for the sudden drop in the curve of the lower carbon. Of these lamps, number 5 shows the longest life, the run not having terminated when the last measurement was made. Here, again, we note the accelerated combustion toward the end.

I am able, at this time, to give the results of some initial and final tests which bring out the joint effect of the coating and the descending arc. Thus Figure 29 shows an initial and final test on lamp 12 (see table 9, tests 4 and 5). The absorption in this case is 16.4 per cent, after 106 hours. Another brand of carbons in this lamp gives the results found in table 10. One notes here a considerably higher initial intensity, but, on the other hand, a much heavier coating, the final absorption after 105 hours being 35.2 per cent. This lamp was fitted with an inner globe of the closed bottom type. The other type of inner globe presents less surface for the reception of the ash, and one would look for a larger light absorption at the end of the carbon life. A preliminary test on lamp 7 (see table 6) shows that the loss in intensity at the end of the life was 36.5 per cent.

In Figure 30, which represents the result of a coating test on an alternating-current lamp, one finds the striking result of *more light with coating than* *without.* (See table 17.) The absorption is 14.3 per cent. It is important here to remember that, with the

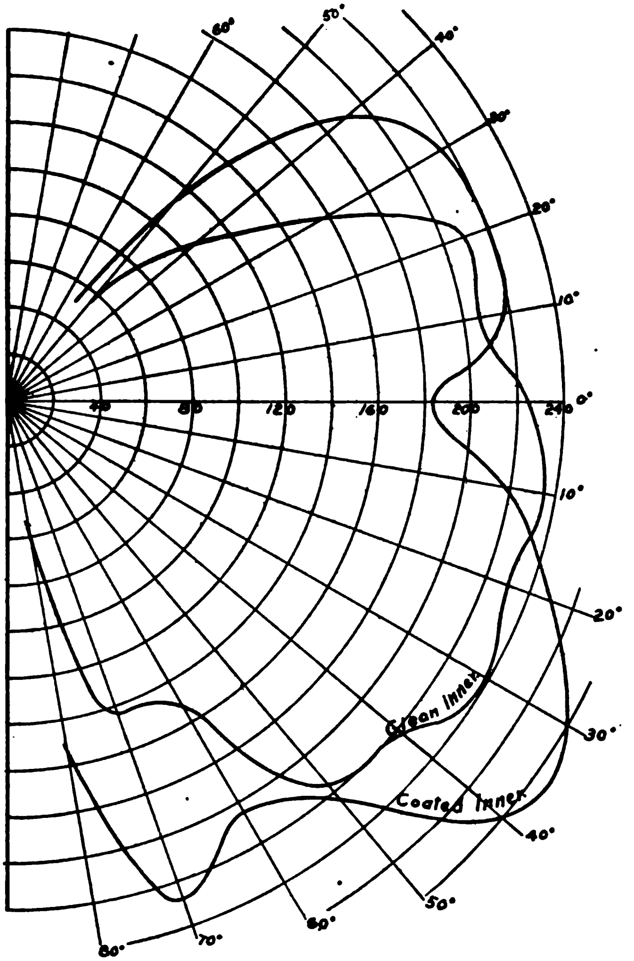

FIG. 30.

arc at the top, the strong upper lobe of the distribution curve of the alternating arc is very much curtailed. Now, as the arc lowers, this lobe unfolds, as it were. In seventy hours' time the coating has not formed with sufficient rapidity to offset this increase in lumininous flux. Hence the result shown.

Respectfully submitted,
C. P. MATTHEWS,
Photometrist for the Committee.

DISCUSSION

THE PRESIDENT: Gentlemen, you have heard this very interesting report; it is now before you for consideration.

VICE-PRESIDENT CAHOON: Mr. President, I am very glad to note that this is a report of progress. The report is one of the most interesting I have ever had the pleasure of listening to, and I think the committee well deserves a vote of thanks on the part of the association for the large amount of time and work that it and its associates have put into the report; and I move you, sir, that the thanks of the association be tendered to them, and that the committee be instructed to continue the investigations further.

The motion was carried.

PROFESSOR MATTHEWS: I should like to say that the work of the committee would have been very difficult without the assistance of the students, who have helped throughout this work, and a full share of credit is due them for their earnest and careful work during the course of these experiments.

MR. SCOVIL: It appears by the financial statement in the report that there is not much more money with which this committee can continue its work. The results accomplished are certainly very valuable and efforts should be made to see that the committee has all funds needed to continue its investigations. Apparently, the committee has obtained most of the appropriation for the work by its own efforts. That is somewhat typical of the association. The members do not take enough interest in such matters as this, which are of vital importance to them.

MR. DOHERTY: Unfortunately, I did not hear all that my friend, Mr. Scovil, said; I was discussing a point in this report with a fellow-member of the committee. This work has been carried out at Purdue University, and about half of the funds required have been provided by the association. It is a line of work that I do not think any manufacturer would voluntarily take up; he could not very well afford to do it. I do not think any of our central stations could afford to take this work up and shoulder it. Experimental work, as done by Professor Goldsborough and Professor Matthews, would be very expensive if purchased. It has been on their part a work of love. The central station is in business to sell light, not current, and yet I know that if there were an opportunity to increase the efficiency of our present arc machines thirty-three and one-third per cent, we should all feel generous enough to subscribe means to gain the knowledge of how to increase the efficiency of our apparatus. If we look at the business of the central station from the right standpoint, we can see that it is one of furnishing light; and if we can bring up the efficiency of our translating apparatus, we are doing the equivalent of increasing the efficiency of our generating apparatus. We shall require more funds to carry on this work; we are simply at an interesting point of the work, just beginning it.

It is natural to suppose that in the future greater attention will be paid to the specifications on which we must bid for city lighting and other classes of lighting. I do not think any of us want to buy apparatus that we must throw in the junk heap a year or two hence simply because we have not had a proper knowledge of the photometric value of arc lamps.

I take it that Mr. Scovil's remarks were in regard to the funds for the committee. We have been expecting to be able to obtain sufficient funds by voluntary subscription. We do not like to coerce any one into subscribing, but a very modest subscription from a great many central stations would enable us to carry the work out to a satisfactory termination. We certainly shall welcome any offer of financial assistance, for it is embarrassing to plead for it; but I think the work as thus far outlined ought to assure any central-station man who feels inclined to subscribe that the investment is not a bad one. I hope every central-station man will put himself in the place of the members of the committee. They are trying to carry on this work, and if they must be charged with the work and also with begging the funds, their duties will become hard and oppressive. But we are in the work to stay, and we will do what we can to get the money. We want the assistance of every member of this association, and of those that are not members, if they will subscribe. The work is for the benefit of all central stations and of the whole electrical fraternity.

MR. W. WORTH BEAN: I move that this matter be referred to the executive session that will convene to-morrow afternoon. At that time some plan can be formulated to take from the shoulders of the committee, which is doing a grand work for central stations, the burden of raising funds.

The motion was carried.

THE PRESIDENT: The point was raised at the meeting of our executive committee this morning that there is entirely too much indifference on the part of our active members to make the association the great good that it might be made to all of us. There are too few of our active members that are at all active; and when it comes to a question of contributions to work of this kind, there is a marked indifference on their part. If these matters do not affect their interests to-day, they may do so in a very short time. As one gentleman said in the executive committee meeting, many of our members are too prone to sit quietly by and appear indifferent until the trouble knocks at their own doors, and then they throw up their hands and appeal to the association for help. I hope that to-morrow afternoon we shall have a full attendance of the members at the executive session. In the course of time these things will be presented to you in such a way that you will be forcibly reminded of what has been said to-day.

MR. SCOVIL: I would ask Professor Matthews if he has made any investigation of the actual illumination of streets where only open arcs are used and of the actual illumination of streets where only inclosed arcs are used?

PROFESSOR MATTHEWS: Thus far, no measurements have been made in connection with that subject. Experiments were made by some of the students in the university a year or two ago that furnish some information on that point, but there has been no thorough investigation of these matters.

MR. WAGNER: I should like to call attention to a few points brought out by Professor Matthews, and also to ask a few questions. It is very apparent from these tests that there is great need of standardization of arc lamps, especially of the inclosed-arc type. The open series arcs used to be classed at 1,200 candle power and 2,000 candle power, and although the rating really meant nothing as to candle power, it came to be definitely understood that a 2,000-candle-power open-arc lamp required 9.6 amperes, or 480 watts. For inclosed-arc lamps, both direct and alternating-current, as manufactured to-day, there seems to be no standard whatever. No attempt has been made to standardize them by candle power, and each manufacturer seems to have a different rating and wattage; and that is most apparent in alternating arcs. Professor Matthews made the statement that, aside from the efficiency as a light-giving source, the direct-current arc lamp was much superior to the alternating-current. Now, that is not due to anything inherent to the alternating-current arc itself, as I understand it; it is really the fault of the manufacturer in making the alternating arc lamps a less source of light than the direct-current arc lamps, by actually using a less number of watts in the alternating arcs than in the direct arcs. Some time ago, in making specifications for arc lamps, I called the attention of one or two manufacturers to that point, and it occurred to me that as we knew the alternating arc was somewhat less efficient than the direct-current arc, it seemed very foolish indeed to attempt to use the alternating arc as a source of light when actually using less power than we were using in direct-current arcs. Therefore, in certain specifications I called for alternating arcs that would consume not less than 525 watts. The average inclosed direct-current arc uses between 525 and 550 watts. Now, why make an alternating arc that consumes less watts, and that we know will give less light? These alternating arcs referred to in the tests average considerably less than 450 watts, and the direct-current arcs averaged almost 550. This is one reason why the alternating arc is not as good a source of light as the direct-current arc. Professor Matthews has stated that, per watt consumed, the alternating arc, with a proper reflector, is almost as efficient as the direct-current arc. I believe that if we use at least as many watts in the alternating arc, we can get almost as much light—we can make the alternating arc almost as good a source of light as the direct-current arc; and taking into consideration the efficiency of transformation and transmission in large stations, it is very possible in many cases to make the alternating arc, considering the whole system, more efficient than the direct. There are many cases, however, in which the direct-current arc must be more efficient. I wish to ask Professor Matthews if I am not correct in making that statement, and if that was not what was meant when he stated that the alternating under certain conditions per watt consumed was as efficient as the direct-current; and if that be true, if the manufacturers were to adopt a proper standard for the alternating arc, whether it could not be made nearly as efficient a source of light for street and interior lighting as the direct-current arc. If that be the case, I would suggest that in the pursuance of this work by this committee, if possible, some means be adopted to place before the manufacturers the desirability of a standardization of inclosed-arc lamps. It probably cannot be a candle-power standardization, but it might be a standardizing on the basis of watts consumed in the arc.

PROFESSOR MATTHEWS: I fully agree with the last speaker regarding the diminished output of the alternating-current lamp as compared with the direct-current. The alternating-current undoubtedly gives less light than the direct-current, but at the same time takes less power. I presume that one reason why some manufacturers do not put more power into the alternating-current lamp, is because of the high current density that would be necessary. You will note that the direct-current lamp takes five amperes, approximately; the alternating-current 6.5 amperes. The reason of such a difference is that you must put more current through the alternating arc to bring up the power, because the arc has a power factor; in other words, the waves of current and electromotive force in the arc, while apparently in phase, are of such shape as to give you a power factor. The apparent power put into an alternating arc is considerably greater than the actual power consumed. To get the same actual power, we shall have to force through the carbons a considerably heavier current; and possibly that is the reason why manufacturers do not bring the alternating-current lamp up to the same wattage as the direct-current lamp. This additional current means a line loss considerably in excess of that with the direct-current lamp. The alternating-current lamp has a distinctive advantage, however, in the fact that the voltage is reduced from the terminal to the arc by inductive resistance.

Mr. Hillman (Schenectady): Mr. Wagner was evidently referring to street lighting, while at the time Professor Matthews spoke on that point he brought up the five-ampere and six-ampere alternating lamps that have been used mostly for interior lighting. It is a fact that one of the prominent manufacturers has produced—and, you might say, standardized—an alternating-series street lamp that takes the same amount of energy as the series direct-current street lamp. When I say that they have standardized this alternating lamp, and when I refer to the direct-current lamp, I mean a 7.5-ampere, series, alternating-current lamp, consuming 480 to 500 watts at the terminals, and, as distinct from that, a 6.6-ampere, inclosed, direct-current street lamp, consuming approximately the same energy at terminals and approximately the same energy at the arc.

You will recollect listening a year ago to Mr. Atkinson in reference to the prospect of changing over his station in Atlanta, and he referred particularly to street lighting. In January last they placed on the streets of Atlanta twenty-five alternating, 7.5-ampere lamps, to compare with the open-arc, direct-current, 9.6-ampere street lamps. The energy at the terminals of the lamps was approximately the same. After these lamps had been in service about three months, the representatives of the lighting company, with the board of city lighting and the members of the common council, investigated thoroughly the actual lighting results from the two systems. There were these twenty-five alternating-current lamps and about eight hundred of the open arcs, so that excellent opportunity was afforded for making a comparison. The board of city lighting approved of the new light in the city of Atlanta, and arrangements have been made between the city and the lighting company for placing on their streets some seven hundred alternating, 7.5-ampere street lamps. During that time the Monongahela Company, of Pittsburg, investigated the street-lighting question, covering some 1,000 lamps' capacity, and after making tests and investigating the systems thoroughly, that company has placed an order with this same manufacturer for 1,000 lights' capacity of 7.5-ampere alternating lamps. The same manufacturer has placed in St. Louis, Mr. Wagner's city, something like 1,000 to 1,500 alternating, 7.5-ampere lamps. The point I wish to bring out strongly is that the larger-current or the larger-energy alternating lamps are being made to-day, and upward of five thousand of them are in daily use. It is true that the lower-energy lamp was standardized, and out of some 12,000 to 15,000 lights' capacity alternating inclosed lamps installed in this country to day for street lighting, probably one hundred and fifteen out of one hundred and twenty-five stations have adopted the lower-energy lamp, consuming about 425 to 450 watts at terminals and a little over 415 watts at the arc. Some of the larger cities have thoroughly investigated the higher-energy lamp, and have had no difficulty in securing samples of these lamps; and there *is* a higher-energy alternating lamp to-day consuming the same energy as the 9.6-ampere open-arc lamp.

MR. GILCHRIST (Chicago): I think, as Mr. Wagner said, that it would be very desirable if we could have standard lamps for comparison; but speaking from the commercial standpoint, which appeals to me most, from our experience here in Chicago, it seems as if the standard should be a lamp requiring less current rather than more. A 450-watt alternating lamp is very much easier to place commercially in Chicago than a lamp requiring more energy; and we have even insisted on the manufacturers furnishing us a lamp that would require only 350 watts. We have not been able as yet to get the results we should like, but I think we may strike a mean between the two, and it will make a good selling lamp. Chicago is going in the direction of small lamps rather than large lamps. One of our very large consumers, who uses 250 arc lamps, uses nothing but three-ampere lamps. A great many four-ampere, direct-current lamps are used in this city, and I think it will be but a little time before the great majority of our arc lamps are three and four-ampere rather than five-ampere direct-current.

PROFESSOR ROBB: I ask Professor Matthews whether or not he has any data of the comparative value of the alternating-current lamps and direct-current lamps where the comparison is limited, not to the mean spherical candle power, but to the mean lighting in the zones from horizontal to ten and twenty degrees below the horizontal? That is the lighting that is most important to us from a street-lighting standpoint. If Professor Matthews has had time to work out a comparison for this particular group of angles, I should be much interested in having him give them to us. I tried to work it out incidentally during the reading of the report, and it seemed to me that the values of the direct-current and the alternating-current lamps were closer in these angles than was the average for the mean spherical candle power.

PROFESSOR MATTHEWS: I might say that no attempt has been made to do that, but there are in the report data that could be worked up in that manner, and the suggestion is a good one. I think those that are interested in the work can do that, and perhaps add such a comparison to the report. Of course it is well known that for the illumination of remote parts the light from zero to ten or fifteen degrees below is the valuable light, because there is an abundance of light below the lamp and for a distance of seventy-five or eighty feet in any case. I think that perhaps the tendency will be toward the definition of what is the useful flux of light from an arc lamp for street lighting. Suppose we were to say that the useful flux of light for street-lighting purposes is that through a solid angle whose value shall be determined by certain fixed distances from the base of a lamp-post of given height. Thus the distances might be seventy-five and 150 feet, and the height that which is found best when a compromise is made between the theoretical requirement of maximum mean illumination and the practical requirements of a suitable mounting or suspension. Having determined conditions like these, the best is that which produces the highest mean illumination under such conditions. The only question is, can we measure this illumination accurately in the street, or shall we depend wholly upon the distribution curves, such as are found in this report? The subsequent reports of the committee are likely to settle this question definitely.

MR. WAGNER: I wish to indorse what Professor Robb said about the illumination near the horizontal, and to emphasize again that for street lighting the rays between the horizontal and about twenty degrees below are the useful rays. We have more than enough light under the lamp, and we want all the light we can get at seventy-five or one hundred feet from the lamp. A standard could be adopted that should specify the amount of candle power at a given angle below the horizontal, say twenty degrees. That need not be measured on the street, but in the laboratory with a lamp similar to the lamp used on the street.

With reference to smaller candle powers and lower wattage, I agree with Mr. Gilchrist that there is a demand for that class of lamps; but we are comparing standards of illumination in this discussion, and we cannot very well compare them on a different basis, and we have been questioning the values of the different classes of lamps for street lighting as much as for anything else. That is what has brought up the discussion in most places—the comparison of lamps for street lighting. With the customer for interior lighting, we can make any deal we wish. He can have a certain size of lamp at a certain price. A small lamp costs less than a large one. The question of substituting alternating arcs for direct-current arcs, mentioned a few minutes since, recalls to my mind the 7.5-ampere alternating arc. Some few years ago I received in St. Louis some of the first inclosed alternating arcs made by a prominent manufacturing company, and they were for six amperes. I got five of them, and they were satisfactory except for the amount of illumination. I was contemplating changing over the entire system of series direct-current arcs, using from 480 to 600 watts in the lamps, open arcs, and I had to find a lamp that could be substituted for those without complaint on the part of the customer. I found at once that six-ampere lamps would not do. They were the largest made at that time for alternating current. I at once specified 7.5 amperes, and received the first lamps made of that type. It was comparatively an easy matter to substitute these lamps for the open direct-current lamps, and it was only a few months before about fifteen hundred lamps were changed from direct current to alternating current. When the question of using some of these lamps in the streets came up before the board of public improvements having that matter in hand, it was decided, after some rough tests on the street and some laboratory tests, that the 7.5-ampere, alternating-current lamp was satisfactory for street lighting, and 325 of the lamps were installed. Prior to that, some five and one-half or six years ago, all the street arc lamps in St. Louis, comprising about twenty-six hundred in all, were changed from open series arcs to open, alternating-series arcs; that being the first installation of any size of series-alternating arc lamps. The arcs used were all of the open type until a few years ago, when a number of inclosed arcs of 7.5 amperes were substituted. A large number of the open arcs are being used to-day, and these lamps consume about five hundred watts, are open, alternating, series lamps, and were accepted by the city in place of 480-watt, series, direct-current lamps. They undoubtedly give less light in spherical candle power, but the useful rays from the horizontal and twenty to thirty degrees under the horizontal, are about as intense as with the old series, direct-current lamps. We use a suitable reflector, so that the entire amount of light usually thrown upward is thrown down as near these angles as possible.

PROFESSOR GOLDSBOROUGH: Touching upon the point brought out by Mr. Wagner, I think it may be of interest to call attention to exactly what economy may be expected from the best alternating lamps. Professor Matthews made tests on two alternating lamps, using a shade, and obtained from these tests the mean hemispherical, below the horizontal, economy in watts per candle. That mean hemispherical economy in watts per candle comes out 1.60. Now, the two best results obtained for direct-current lamps—that is, the best economy per candle power, mean hemispherical rating—come out 1.65; so comparing the best results from the two systems, we have 1.60 for the alternating current using a shade, and 1.65 for the direct current.

If all the alternating-current lamps tested had been provided with shades, I am quite sure that the alternating-current lamp would have shown up quite as well as the direct-current lamp in mean hemispherical candle power, that is, on the basis of watts per candle. Presumably, it would have come out 1.6 watts per candle, mean hemispherical candle power.

MR. WAIT (Chicago): I would ask if the watts referred to are watts at the terminals or watts at the arc?

PROFESSOR MATTHEWS: Watts at the terminals in every case except where specified to be at the arc.

MR. WAIT: In other words, what Professor Goldsborough has just stated refers to the watts at the terminals, and if the watts at the arc alone were considered, the direct-current lamp would have thirty per cent higher efficiency than the alternating-current lamp.

PROFESSOR GOLDSBOROUGH: No; just the other way. The watts at the arc, if I mistake not, are higher in the direct-current lamp than in the alternating lamp with the reflecting shade, the mean hemispherical candle power being taken. If the watts in the arc in each case had been divided by the hemispherical candle power taken with the shade, the result would have been to the advantage of the alternating-current lamp.

MR. WAIT: Is that the way you understand it, Professor Matthews?

PROFESSOR MATTHEWS: There is plenty of evidence of the fact that the direct-current arc, considered by itself, devoid of any mechanism, is considerably more efficient than the alternating-current arc without the shade. That is explained by the fact that in the direct-current lamp we have a large positive crater at a temperature said to be

3,900° and a negative crater at 2,700° Centigrade. In the alternating lamp we have a crater that is positive and negative alternately, and its temperature is doubtless somewhere intermediate between the other two. Moreover, its area is much less, so that out of the alternating lamp without the shade you are going to get less light per watt than out of a direct-current lamp; that is, considered apart from any mechanism. The matter of determining the proper ratio is, as I said in the report, a complex one, because if you take the alternating arc and supply it from one machine it will give a certain light, and if you supply it from another machine using the same power it will give a different light, because the light depends on the shape and intensity of the wave and on the amount of inductance in the circuit. One alternator may have a different inductance from another, and consequently the power factor of the arc will change with the change of inductance of the circuit outside of the arc.

Taking watts in the arc per mean hemispherical Hefner unit, we find 1.29 for the alternating arc with shade and 1.41 for the direct arc with clear outer globe; which is to the advantage of the alternating arc with shade, as Professor Goldsborough says. If, however, we take the single case given of a direct-current lamp with *no* outer globe—namely, lamp 1—the value of this ratio is 1.11; which is to the advantage of the direct-current arc.

MR. WAIT: Comparing the best direct-current lamps with the best alternating-current lamps, the direct-current lamp will give, say, roughly, thirty per cent more light per watt in the mean hemispherical candle power.

PROFESSOR MATTHEWS: I think my figures will not show so much as that. You will recall that I stated that the result I previously published showed too much.

Mr. Wait: Another point to which I wish to call attention is that the alternating lamp in that case has a shade on it. In looking over the curves in the report, it will be noticed that although the light in the upper hemisphere of the direct-current lamps is a great deal smaller than in the lower hemisphere, there is about as much light as in the upper hemisphere of the alternating-current lamps; so that if we put a shade on the direct-current lamp, we should get about as much additional light in the lower hemisphere of the direct-current lamp as we obtained by the use of the shade with the alternating lamp.

Some of the speakers have referred to the light between zero and twenty degrees below the horizontal as the useful angles. The light at angles near the horizontal is undoubtedly the most useful light emitted by the lamp if we wish to consider a fixed minimum of illumination between lamps long distances apart. If, however, we are considering the illumination from lamps placed close together, as they would be in shops, or in the business district of a city, the most useful angles fortunately correspond very nearly to those where the greater part of the light is emitted. If, instead of considering the minimum illumination on the street surface from lamps placed some distance apart, we should decide that the average illumination was a more reasonable figure, we should find that the light at angles below twenty degrees would be more serviceable in bringing up this average. There has been some tendency among electricians lately to regard a specified minimum intensity of illumination on the street surface as the proper means of determining the value of street illumination. This has quite largely come about from the fact that alternating lamps give so much light relatively near the horizontal angles, and placing them in competition with direct-current lamps, has brought out the fact that the only way in which they can compete with the direct-current lamps, when consuming the same watts at the arc, is to disregard all the other angles except those near the horizontal.

We should be very careful about exerting any influence toward establishing a minimum basis for specifying street lighting, as we are thereby playing into the hands of the Welsbach people. As the intensity of light decreases in proportion to the square of the distance from the lamp, by an inflexible law, it follows that where we are trying to do lighting from arc lamps located some distance apart, we cannot compete with Welsbach or incandescent lamps placed nearer together if the minimum light is all that we have under consideration. Personally, I think that the minimum value is not the one that should be used, but that a mean illumination is more desirable. For example, it would seem that if you have two systems of street lighting giving the same minimum illumination of, say, one-one-hundredth of a candle foot, if one of them gives ten times a higher mean than the other, there is no doubt that it is a much better system. Suppose we take a concrete case, calling for a minimum illumination of one-one-hundredth of a candle foot without any other restrictions. This intensity of illumination is what you would get from one candle at a distance of ten feet, and is about what the intensity of illumination would be between two arc lamps 600 feet apart. It is evident that if we obtained this minimum by a number of very small gas burners placed close together, we should nowhere get much more than the light from a candle ten feet away. This intensity is so low that a man could not read a time-table or even his watch, while with the arc lamps giving the same minimum he could quite readily do either as soon as he began to get away from the minimum point, and there would appear to be no question whatever but that the arc lamps were the most satisfactory system.

Mr. White (Cincinnati): There are several conditions that must be borne in mind in order to avoid confusion in the discussion of this question. We have two classes of lamps, alternating and direct. We have two conditions, indoor and outdoor. We have two methods of supplying current to the lamps, depending on whether the lamps are multiple or series burning. The tests that have been thus far given are on multiple lamps, and therefore in a discussion as to the efficiency per watt, results are very different from what they would be if we were discussing street lighting where the lamps are in series—where we do not have the reactive coils with the alternating lamps and do not have dead resistances with the direct-current lamps. In indoor lamps, under proper conditions, using inductive resistance for alternating-current lamps and dead resistance for direct-current lamps, we shall find that the alternating lamp will give as efficient illumination, watt for watt, at the lamp terminals, or as efficient illumination, watt for watt, at the switch board, as will the direct-current lamp. We must consider the illumination per watt, whether it be alternating or direct-current. The size of the lamp whether it be three-ampere direct as compared with four-ampere alternating, does not matter; it is a question of the watts in comparing these cases, and not of the amperes; and watt for watt, either at the lamp terminal or at the switchboard, we shall get as good efficiency under the best conditions with the alternating as with the direct-current lamp.

In considering the efficiency of lamps for street lighting, conditions have a great deal to do with the case. If you are in a large city, and there is a prodigal expenditure for street lighting, as in some of the boulevards of Chicago, where there are lines of arc lights on both sides of the street fifty feet apart, you have one condition; in the business part of a small town, where lamps are 300 feet apart, you have another condition; in the residence portion of a small town or city, where lamps are on an average two blocks apart, so that they have to light one block or about 300 feet each way, you have yet a different condition. Where lamps are close together, an open 9.6-ampere lamp will give you better general illumination than either of the inclosed lamps, because the lamps are so close together that the maximum light at forty-five degrees, with the ordinary height of the lamp from the street, will give uniform illumination. If the lamps are 300 feet apart, so that they must light 150 feet each way, you will possibly get a better light with a 6.6-ampere, series, inclosed-arc, direct-current; and if your lamps are two blocks apart, I think you will then get better results with a 6.6-ampere alternating lamp. You can very easily determine for yourself under actual conditions which is the better lamp. Take a 9.6-ampere, direct-current lamp, which most of us have, and have one at one street intersection, and at the next intersection have a 6-ampere, alternating, constant-potential, and take a photometer disc—you do not need any scale or candle—and get midway between the lamps and see which side of the disc the shadow is on most of the time. You will find that it will fluctuate, part of the time in favor of the direct-current open lamp, and part of the time in favor of the alternating-current inclosed lamp; but if the lamps are far apart, you will find that a great portion of the time the shadow is in favor of the alternating lamp. That is purely on account of the greater horizontal illumination that the alternating-current lamp has as compared with the forty-five-degree maximum of the direct-current open lamp. You will find that the alternating lamp has a smaller luminosity under the lamp; but this is an advantage when the lamps are far apart, because the greater the volume of light under the lamp, the poorer for street lighting. At a distance of 300 feet apart, the alternating lamps will give you more light than the direct-current lamps, which is also an advantage; so the alternating lamp with lamps far apart is better, both near to the lamp and at a distance, and for that reason we cannot set any one rule that will apply to all cases. It is impossible for this association to say that a 6.6-ampere direct-current, or a 6.6-ampere alternating-inclosed, or a 9.6-ampere direct-current open lamp, is better in all cases, because the conditions vary.

If you are figuring on street lighting you do away with the loss in the direct-current lamp due to dead resistance, and you therefore wipe out much of the advantage of the alternating due to the inductive resistance. The amount of light per watt with series lamps, without dead resistance, using direct current, is much greater than it is with the alternating lamp per watt. If you want to compare the alternating with the direct current for series lighting, you have to make up for the saving, due to the throwing out of the resistance, in the direct-current lamp by other savings in the alternating system that must be found outside of the lamp. That saving will be made up in the use of direct-connected alternators and the cutting out of the belting and counter-shafting, and in the greater efficiency of the direct-connected alternator as compared with the belted arc machine.

I should like to leave this impression in regard to indoor lighting with multiple burning, that the alternating-inclosed arc will hold its own very well if installed under proper conditions. For street lighting, if you are using multiple lamps, as some of the Edison companies are doing in the downtown districts, supplying them from the underground mains, the conditions are similar. For street lighting with series lamps, the direct-current lamp has the advantage over the alternating-current lamp in the lamp itself; but the alternating-lamp system has an advantage in generation and distribution. Which lamp, therefore, is better in any particular case, depends on the distance apart of the lamps and on other conditions outside of the light efficiency per watt of any one class of the lamps named.

THE PRESIDENT: The final business of the morning session is a report of the committee on grounded circuits, of which committee Captain William Brophy is chairman Captain Brophy is not present, nor has he sent his report, and that matter will therefore lie over until a later session of the convention.

The meeting then adjourned until 2.30 p. m.

SECOND SESSION.

The meeting was called to order at a quarter before three by President Carnes, who announced that the first business of the session would be a paper by Mr. Harry J. Frith, of Watseka, Illinois, on the subject of exhaust steam heating, to be followed by remarks on the same subject by Mr. F. A. Copeland, of La Crosse, Wisconsin.

Mr. Frith presented the following paper:

UTILIZATION OF EXHAUST STEAM FOR HEATING.

The net earning of an electric light or power plant is represented by the gross income less the operating expenses and fixed charges. In all cases it is desirable that the greatest return or net earning be produced on the money invested in the enterprise. To accomplish this result, each expense item must be reduced to a minimum, and all productive factors — men, machinery and equipment — worked to the fullest capacity.

Unfortunately, the electric load runs up to a peak of short duration, and machinery of ample capacity must be provided to carry the peak load, requiring investment oftentimes out of proportion to the average load. Boilers, in particular, prove inefficient on account of the short duration of their operating period. Could the boiler load be continuous, the efficiency would be greatly increased, and any plan that will produce a more uniform boiler load is a step in the right direction.

While the hours of the station employees are usually a little long, the actual labor performed is light, and if a uniform load were available (say nearly equal to the peak), it could be cared for without additional labor expense. This is impossible; then, as nearly as practicable, each man and each piece of apparatus should fulfill those conditions which (provided the returns are sufficient) increase the net earning, accomplishing a much desired result.

As ways and means to this end, I shall take up the production of current and resulting by-products. The primary operation is the production of steam by burning coal in the furnace, which gives steam and waste in the form of fuel gases, radiation of heat from the furnace, etc. Ashes are left as a by-product of more or less value, as in most places a ready market for them exists. Aside from this insignificant saving, there is in the steam generator no particular by-product that can be utilized, except in large plants, where the flue gases may be put through fuel economizers and part of the heat in them be saved.

The efficiency of a tubular boiler under test conditions is probably very nearly seventy-five per cent. However, under ordinary conditions, as found in the smaller class of plants, sixty-five to seventy per cent, probably more, nearly represents the results obtained. Clearly, there is little or no chance of bettering this part of our station unless means are found whereby the boilers may be kept under a more even load.

The next operation is the use by the engines of the steam generated in the boilers whereby some eight or ten per cent is utilized; that is, ten per cent of the available heat is converted into work. This, I believe, is a maximum figure for plants using simple engines run non-condensing. The engines deliver some ten per cent of the heat of the steam in the form of power, and waste the remaining ninety per cent in the form of exhaust. Of this exhaust, which may be considered a by-product, something can be saved in heating feed water, so it is safe to say that fully eighty per cent of the heat delivered by the boiler is, while a valuable by-product, thrown away and wasted, and represents a large portion of the operating expenses. Not only is the heat thrown away, but nearly all of the water evaporated is also thrown away. If this water were saved it would not have to be replaced with fresh water, and much trouble with dirty boilers would be avoided.

The other losses in transmission and conversion into electrical energy are well known, and are small. The heat in the exhaust represents the largest loss of a by-product, and I shall consider means for saving it and converting it into a profit. Can this be saved and made to yield a profit? I believe it can by using the exhaust steam for heating purposes. However, we should have an *ideal* system. The saving and sale of this heat, and the saving of the water of condensation, require careful consideration, and I shall try to take the matter up in its various phases.

The temperature of exhaust steam, without back pressure, is 212 degrees Fahrenheit, making it applicable only for heating buildings. To use this for heating purposes from an exhaust-heating central station, it is necessary to have a proper distribution of the heat to the points of consumption; and in distributing heat from a central station to distant points, one is confronted by a problem of no mean proportions.

First, the heat must be conducted through pipes, which must be well insulated, to prevent radiation and loss.

Second, the heat must be moved rapidly.

Third, the heat in the exhaust steam must be used without placing any back pressure against the engine, for back pressure is a serious detriment to the efficiency of a steam plant. The ordinary engine working under economical conditions with a steam pressure at the throttle of eighty-five pounds shows a m. e. p. of thirty-five to forty pounds if there be no back pressure except that required to overcome friction of the exhaust steam in its passage through the exhaust ports to the atmosphere. Back pressure detracts from the load-carrying capacity of the engine. Even five pounds back pressure means one-seventh of the power of the engine thrown away. To be sure, this may be offset by increasing the boiler pressure by some ten pounds; but this is not an economical operation, and in many cases it is impossible.

Fourth, the system for furnishing this heat must be able to supply any class of consumers.

A system in which the radiators are always at or above a certain fixed temperature, regardless of the demand, is similar to burning lamps all day to have light for the night. It is very evident that in an ideal system the regulation of the degree of the heat circulated must be under absolute control, so that a suitable heat may be furnished on a mild spring or fall day as well as during a winter blizzard and all intermediate weathers. In a steam system the radiating surface is always at least 212 degrees. A necessary feature in successful heating is lost, for either all of the heat or else none is available; and on mild days, with the heat all on, the windows must be opened to reduce the temperature, and with the heat all off it is too chilly for comfort. The heating period has very few blizzard days annually—perhaps a dozen—about thirty days of zero weather, and the rest is weather wherein the temperature ranges from seventy degrees down to zero. This puts the system at maximum capacity for a dozen days, medium capacity for about thirty days, and under a light load for the greater portion of the time; the last condition prevails for fully three-fourths of the season. Clearly, regulation and ability to furnish mild heat are very important features, and in an ideal system the degree of heat must be under absolute control. In other words, there must be distributed just enough heat at just the right time and place; and a system in which the degree of heat cannot be varied at will must of necessity be wasteful during the period of light load.

Fifth, it is necessary to convey this heat from the central station to the various points of consumption in an efficient manner. For the accomplishment of this it is essential that there be minimum losses of heat by radiation in the mains underground, which requires a rapid movement of the heating medium; this operation must also be accomplished with a minimum expenditure of power. The circulating device must be reliable and inexpensive to maintain; otherwise there will be a loss of power, and consequently of efficiency.

The entire system must be reasonable in first cost, in maintenance, and in operating expense; must be simple and reliable. There must be no weak points in it. It must be compact, and must occupy little space; must be neat in appearance, and durable. All complicated parts and automatic devices must be avoided, as these are notoriously liable to get out of order, and give more or less trouble requiring expert attention. The system must be so constructed and installed that the depreciation account will be kept down to a minimum.

There must be provision to heat the boiler feed water, or, better still, the exhaust steam should be condensed, filtered to remove any oil, and returned to the boiler at a high temperature.

What is an ideal system? Perhaps the best way to determine this will be to take up the various ways and means of central-station heating, and consider the advantages and disadvantages of the features that will help in the selection of an ideal system.

The exhaust steam from engines may be used as in the ordinary exhaust-steam heating system. In this case it is delivered direct into the mains, and driven to the points of consumption at a greater or less expenditure of power. To drive this steam, and to increase the temperature in cold weather, it is necessary to carry a back pressure against the engines furnishing the exhaust. Some time since, while investigating the heating question, I found that one station carried a maximum back pressure of seventeen pounds, another of eighteen, another twenty; about half of the ordinary m. e. p. of a simple engine working at maximum efficiency. In another case I found that the maximum back pressure was thirty-eight pounds, which equals the usual m. e. p. In this latter case all the engines were high-speed simple engines, and such a back pressure seriously affected the power delivered by the engines, requiring, too, an abnormal consumption of fuel. In fact, I believe it would actually have required less fuel to produce the results if the exhaust had been turned out of doors and the heating mains connected direct to separate boilers. I observed at another time a back pressure of four pounds, with the outside temperature at sixty-three degrees. At the same time a hot-water plant was producing more satisfactory results to its patrons with water leaving the station at 130° Fahrenheit and returning at 115° Fahrenheit, requiring an expenditure of less power to circulate the water than would be represented by less than one-half pound of back pressure;

and there was actually no back pressure other than that which occurs in all engines, due to resistance of parts and exhaust pipes. Clearly, back pressure, even in a small amount, must be avoided, as it is more expensive than equal boiler pressure; for if the point of admission remains fixed, we must raise the boiler pressure nearly a couple of pounds per pound of back pressure. We have also to consider that engines do not usually work as well when laboring against a back pressure. The increased steam consumption calls for the evaporation of more water, and consequently for more labor to keep the boilers clean and the furnaces in repair.

Again, with the use of exhaust steam direct into mains and radiators, there is at least 212° Fahrenheit or more. The increase obtainable at the expense of a back pressure is limited (not considering any objections to a back pressure) to 250° Fahrenheit, the temperature of steam at fifteen pounds pressure. This is a small range when compared with water, which may be varied from seventy degrees to two hundred degrees or more.

With a system of exhaust steam direct into the mains, all the condensation is lost, together with the best in the condensed steam, something like 140° of which is available, and is thrown away into sewers. All condensation of any live steam that may be used in time of an insufficiency of exhaust is also thrown away, and this is a most important loss. If a sewer system is not available into which to discharge the condensation, then one must be provided. The hot condensation discharged into sewers often causes disagreeable odors to back up into plumbing, and calls down the wrath of the health authorities. At all air vents cylinder oil causes unpleasant odors to give the system a bad name. Then, too, a system of piping that will hold air or water, will leak cylinder oil and cause more or less trouble from this source.

Since the range of temperature in steam-heating mains is from forty to 250°, greater care must be taken to provide for expansion and contraction than in a system where the range of temperature is through narrower limits; and because the temperature of steam systems runs higher than that of water systems, it follows that better and more expensive covering must be used. There is no perfect covering, hence condensation must take place in the mains. This requires that steam mains be carefully graded to avoid pockets, and where pockets are essential, means must be provided for removing condensation. Water mains, on the contrary, can be run regardless of grade.

Strange as it may seem, I have been credibly informed that in case of shut-down, or of a deficiency of heat in extreme cold weather, a steam system is more apt to freeze than hot water.

The drift of my talk, then, is toward the ideal system, and it is hot water. As a medium for transmitting heat, water has no equal. It meets all the required conditions, and is acknowledged by engineers, architects, and even by the medical profession, to be the ideal heating medium for residences, stores and public buildings.

With a hot-water system as our ideal, then, how can it be best applied to our needs?

It is evident that the water must be heated in a tubular heater similar to a closed feed-water heater or surface condenser. It is important that sufficient opening be provided through the tubes so that all the exhaust steam can pass through the heater and to the atmosphere without producing any back pressure on the engines. In other words, there must be an open and free exhaust pipe at all times. Sufficient surface must be provided to condense all the exhaust steam delivered by the engine and to allow none to escape. The water is circulated through the space around the tubes, where it absorbs the latent heat in the steam, condensing it. The circulation should be rapid, so as to make the surface efficient. The condensed exhaust steam may be collected in a suitable settling chamber, or filtered to remove the grease, and then the clean hot water, now freed from all injurious matter, may be returned to the boiler. All the condensed exhaust steam is then saved, and not only is the pure water obtained, but all the heat in it is saved as well; and that means probably eight per cent of the heat in the exhaust steam, making just so much more available for sale.

In addition to using the heat in the exhaust steam, the system must have heat at all times when no exhaust, or an insufficiency of exhaust, is available. Heat must then be supplied from another source, and this may be done in several ways. A live steam connection may be made to the exhaust pipe and live steam blown into and mixed with the exhaust; and in some instances this is done, but the method has objections that seem to make it impracticable. In order to prevent too much live steam from being blown through the heater and to waste, the live steam must be supplied through a reducing valve, and a back-pressure valve is installed in the exhaust pipe to afford a pressure against which the reducing valve can work, thus causing the engine to work under a back pressure. Then, too, the live steam thus used becomes mixed with the greasy exhaust, and not only must be pumped back to the boiler before it can be used over again, but must be purified as well. All this calls for extra care and attention.

Another method for supplying extra heat, in use in some places, is to circulate the water through an ordinary boiler, and thus heat the water in a hot-water boiler direct from the fire. This means that at least two boilers, or two sets of boilers, must be kept going; one set must keep steam to drive the pump used for circulating the water, and the other set heat the water; so an unnecessary number of fires must be kept going. The regular boilers and furnaces must cool down somewhat, and the extra boiler and furnaces be heated up; in the latter, instead of the boiler being at some 323° or 340°, the boiler is at a temperature of 200° or less. This means that the furnace gases are apt to be chilled, and an imperfect combustion will result. From this come more smoke and soot, and a loss of efficiency in general; and this is in addition to the loss of efficiency due to the cooling and idleness of the regular boilers. It is a well-known fact that the best results are obtained from fuel under a boiler that is in constant use. Therefore the regular boilers should be kept hot as much as possible, and separate hot-water boilers should not be necessary whenever the plant is a little short of exhaust steam. Then, too, extra boilers require extra space in the station and a heavy added first cost.

The way, then, to add heat to the system, aside from that furnished by the exhaust steam, is to use steam drawn from the regular boiler plant and used in a separate heater; one similar to, but, of course, not so large as, the exhaust heater. This heater should be set above the boilers, so that the water of condensation will return to the boilers by gravity and at as high a temperature and with as little loss by radiation as possible. A separate heater permits the use of the full amount of heat in the steam without the possibility of wasting any steam. This condensation is kept absolutely free from oil or other impurities, and is returned to the boiler, saving the need of filtering it and of all power required to feed it into the boiler. This, I believe, is the most efficient means of supplying such extra heat as is required. By its means, in extreme blizzard weather, the full benefit of the exhaust may be obtained with no back pressure; and the water can be raised to a point above that of the exhaust, if necessary, in a far cheaper manner than by carrying back pressure to get such results. The boilers are also regularly under heat; the furnaces always hot, etc. Thus, in the ideal system we shall have a separate heater, for heating the water in time of insufficiency or absence of exhaust steam, set in series with the exhaust heater, with by-passes around each of them so that either may be cut out of service if so desired.

With means provided for heating the water, we can now consider means of circulating it from the central station to the customers. In some instances duplex or single-acting, reciprocating plunger pumps have been used. As is well known, a steam pump uses steam non-expansively, and consequently is perhaps the least efficient steam motor in the market to-day. In some instances, as much as 125 pounds of steam per horse-power hour are required. In addition to inefficiency, pistons must be packed and cared for, valves must be looked after and renewed. Each stroke gives a pulsation to the entire system, the noise from which is apt to prove annoying to the patrons. This type of pump also requires considerable floor space, and is expensive in its first cost. The pump for use with a hot-water heating system must be more simple, more durable, and by far more efficient. The centrifugal or blower type of pump best meets the requirements. For moving large volumes of water against moderate heads, no type of pump is so efficient as this. In addition to being much more efficient from the hydraulic standpoint, this pump may be driven from the most economical source of power available. If a line shaft be run continuously, the pump can be belted from that, and the horse power required be that produced from twenty-six or thirty pounds of steam per horse-power hour. If current be available, one pump may be driven by a direct-connected motor and the duplicate unit may be driven by a small, direct-connected, high-speed engine; thus, in any event, using the minimum power for the maximum result. These centrifugal pumps give no pulsation whatever. They turn out a steady, even, continuous stream. There are no valves at all to trouble, and there is nothing about them to get out of order. In fact, there is merely a rotating disc in a chamber. There is nothing about them to break or wear out.

This completes, then, the station equipment required; exhaust heater, live-steam heater and pump for circulation.

We may now consider the system of distribution, or piping of the territory to be covered by the system. It is quite true that, to a considerable extent, the laws that govern electrical circulation hold for water circulation, and the electrical terms employed may be used with advantage to describe the water circuit.

The houses may be put in multiple; this requiring, of course, two mains wherever customers are obtained. One pipe would be the out-bound pipe, and the other for the return water. While at first glance this would seem to answer, yet it is evident that the farther out from the station the customer happens to be, the less pressure there is between the two mains, and therefore less tendency to circulate. In other words, the houses near the stations short-circuit the houses far away, and in order to overcome this tendency to short-circuit, the taps or service cocks must be made larger toward the ends of the line. Thermostats, too, have to be called into play in each house in order to assist in equalizing a badly-designed circuit by cutting in resistance in short circuits. To overcome the tendency of the last house on the line to cease circulating, the station pumps must be operated under enormous pressures, even sixty and seventy-five pounds being used in some instances. Such heavy pressures require enormous pumps.

The two-pipe system, in certain cases, and properly laid out, is an excellent device. The objection to it is that two pipes of a given size give double the radiating surface that one would give. Two pipes cost nearly double what one would cost. There are twice the fittings and joints to trouble, and twice the provision for expansion must be made. A single-pipe circuit, then, offers the solution to these difficulties. One pipe run in a circuit will answer the purpose of two. The houses may be shunted off from the pipe, taking advantage, wherever possible, of whatever tendency there may be to circulate, due to gravity. In this system, there will be required one medium-sized main for each circuit. It can be put in for a minimum expense as to cost of pipe, insulation and labor for laying. This main would be free of obstructions and of low resistance, consequently it would require a minimum power to produce a rapid circulation, which will insure that the load can be carried with small drop. If the main be proportioned properly to the load, with a certain speed for circulation, there can be obtained any predetermined drop in temperature, which should be only twenty degrees Fahrenheit, or such a matter; thus putting the last on practically an even footing with the first. The service pipes need be only of medium size and but slightly more expensive to install than smaller ones, and they will be cheaper to operate, because of less resistance and some aid from gravity, thus reducing the circulating power and producing an economy. With this system of piping, then, twice the territory can be covered with a given length of pipe, by using a shunt system, that can be covered with a multiple system and at a much less expense, and it will be far more economical as to the loss of heat by radiation than is the two-pipe system.

The system may be an "open" or a "closed" one. By an "open" system I mean a system wherein the circuit at the station is open into a tank, and there is at that point no pressure. The water must be pumped from the heaters into the outbound mains and raised to the highest radiator, thence flowing back through the return mains, it runs into the tank. Thus it is evident that the two-pipe plan must be used when the circuit has an open tank at the station. In other words, the pump not only has to circulate the water, but has to overcome the static head of the system—an enormous waste.

If the system were closed—that is, had no open spot in it—then the static head on both suction and discharge would be equal, and the only work the pump would have to do would be to overcome friction.

in the circuit; it would not have to lift any water at all. This would cut the pumping head down to less than twenty pounds, when in open circuits it is often as much as seventy-five pounds. It might be assumed that this power would not be a loss at all, as the exhaust from this power-producing source would be used for heating purposes; but this power is called for twenty-four hours per day, and it is probable that the steam-producing agents in our plant have now enough during the peak of the electric load without added burden, and during a large portion of the time the exhaust from the electrical load is sufficient; so for a couple of hours during the peak it would distress us to produce this excessive power, and during a large portion of the twenty-four hours we should have to throw it away, as our electric load gives a sufficient amount. Any extra pumping required is a great detriment, instead of being merely unobjectionable or of no value.

In the electric station it is of great advantage to use storage batteries, charging them during the period of light load and using them to assist when the heavy load comes. Is there an analogous case in heating? The maximum exhaust is produced at the time of the peak; can this advantageously be saved and stored for use during the time of insufficiency of exhaust? It is evident that the load of a heating plant is limited only by the size of the electric station, as the lights required in any building will furnish only some twenty or twenty-five per cent of the exhaust required for heating it. The proper size, therefore, for the heating system is such that in the usual winter weather it will require all the exhaust except a little during the peak.

Consider the two sides of the storage tank: First, assume a ten-per-cent loss of heat in circulation. To do this it is necessary to have the medium move at a rate of from four hundred to five hundred feet per minute. What size of tank would be required to hold sufficient water, with its stored heat, to supply mains from three to five-inch, four to five-inch, or six-inch, running at this speed? It would necessarily be of immense size, expensive, occupying much room, and it would itself present a very large radiating surface, requiring extensive insulation, and would then lose much heat. Second, there would be only a little surplus exhaust during the peak to apply to heating the storage. In usual weather this would hardly be sufficient to care for the radiation of the tank alone. There would not be enough under any circumstances to justify the installation of a storage tank. Third, in blizzard weather there would be no surplus for storage. Fourth, in mild weather there would be no need of a storage tank, for there is then sufficient exhaust at all times. Even in the case of a plant without day load, I doubt the advisability of using a storage tank, because the stored water can be used but once, as its storage capacity is limited to the drop on the line of some twenty degrees Fahrenheit, because of the immense size required to make it of any actual value, and because of its cost, etc. It cannot prove a paying investment.

In extreme cold weather put on an extra fireman, or use a little better grade of coal, and use the live-steam heater to make up for the extra cold.

To get the best results the equipment must be worked at its rated capacity in ordinary weather, and to its extreme capacity in the coldest weather; otherwise the best efficiency is not obtained.

This about covers the principal requirements for an ideal system, the summary being as follows:

A hot-water system, using closed heaters to absorb the exhaust heat, with sufficient openings to allow all the exhaust to pass through without producing any back pressure, or capacity to condense it all.

A similar smaller heater to help out the exhaust, set above the boilers that the condensation may be returned to the boilers by gravity.

Save all condensation.

Centrifugal pumps, suitably driven, with a closed, one-pipe system of distribution, well insulated.

A load requiring about all the exhaust in medium winter weather; which gives a system wherein the maintenance, operation and investment are minimum, and the efficiency, reliability, simplicity and satisfaction to all are maximum, making an ideal system.

DISCUSSION.

THE PRESIDENT: Gentlemen, you have heard this interesting paper. If there is no objection it will be received and published in the minutes.

We will now hear Mr. Copeland open the discussion.

MR. COPELAND: After listening to this paper on hot-water heating by a gentleman so able as Mr. Frith, I am rather thrown off my calculations. The paper was carefully prepared, Mr. Frith speaks from knowledge, and we will presume that he has an ideal system. He is perfectly right, I think, in stating that the proper way to distribute heat is by hot water instead of by steam; there is no doubt about that, because there is no agent that will carry heat so far as water. Mr. Frith evidently has the single-pipe system. Last year we put in a system that has two pipes. I examined into the merits of both systems before putting in any, and according to my own judgment I concluded that the two-pipe system would be best. To be sure, it costs a little more, but yet you have to make the circuit around back to the station. It appears to me that I can get heat to the farthest end of my system better than if I tap the pipe and reduce the temperature of so much water as goes to heat a building and put it back into the main pipe again. It would seem to me that when the water got out to your far end, if you used much of it, it must be at a very much lower temperature. Of course I do not know much about the single-pipe system. We have in 16,250 feet of double pipe. We start with an eight-inch pipe and run it out 2,600 feet, then 2,200 feet with seven-inch, and the remainder with five-inch pipe. I can put the water out a mile and a quarter with a loss of not more than six degrees. I have heard of the single-pipe system; there is one in Iowa where they have been heating and returning the heat to the station at a loss of only nine degrees. If there is a loss of but nine degrees, where have you furnished any heat? Can you furnish the heat and keep it, too? I no not think you can.

We use the ordinary heater, a heater that is made for this purpose; merely a surface condenser, containing 500 square feet of five-eighth-inch tubes. We have had during the winter 33,000 square feet of radiation. We circulate the water once in an hour and thirty minutes only. In extremely cold weather we reduce that time to about one hour and twenty minutes. We go out a mile and a quarter, and are pretty well scattered, having only thirty-nine customers on this 16,000 feet. We have no trouble in heating them, and the only complaints that have been received are that they have been kept too warm.

We were so anxious to give good service that we sent the water out hotter than was necessary. I think a building should be equipped with sufficient radiation to keep the temperature at seventy degrees with a temperature of not over 190° in the water. We have auxiliary boilers through which we can pump the water in case we do not get enough exhaust steam, and find the boilers to be more economical than live steam. We do not allow any back pressure on the engines, and when the temperature is, say, forty to fifty above zero, with what exhaust steam we get from the pump we can keep the water warm enough, and should not send it out over 130°, probably. When the temperature is fifty to sixty degrees, or a little below that, we can afford to run our engine non-condensing, and fire one of the boilers through which the water passes to get the heat rather than to use even the exhaust steam.

The customer finds the service satisfactory and cheap, and that it costs him less in dollars and cents. You can furnish him more heat units for less money than it would cost him to do the heating himself. If he has his own plant, and it gets a little cold at bedtime, he will go to bed and get warm and build a fire in the morning. If he is being supplied with hot-water heating, he will stay up at nights to enjoy the comfort of a warm room, just as when a customer is burning electric lights he will use them to enjoy the light.

From our customers, using 33,000 feet of radiation, we have a revenue of $4,600. In order to get at the cost (of course this is confidential; forget it as soon as you get outside, but I want to give you my experience exactly), the only way in which I could determine the amount of extra fuel for heating was to take our fuel bill for the year ending April 1st, 1899, and then add to that the increased cost of fuel this year and the increased electric-light load, and then I concluded that the difference was what it had cost us to heat the water. It figures out $2,597 on a $4,600 income. You must take into consideration that we have 33,000 feet of pipe in the ground. We can put on three times as many customers as we have—increase it one hundred or one hundred and twenty—and the loss from radiation in the ground would be no more than it is now. Therefore, the more customers we get, the less fuel, relatively, it will take to furnish the heat.

In regard to the pressure on both sides of the system, we have no pressure on our return pipe. Our station is lower than any radiator, and must therefore elevate the water 100 feet and carry forty-five pounds pressure in order to make the heating certain at 100 feet. We carry four pounds pressure on the highest radiators, ninety feet high. We have no difficulty in distributing the heat equally to all of them. The taps near the station are a little smaller than those farther out. We were advised to put in a three-quarter-inch tap and run an inch pipe into the house; but experience has proved that for a house with 600 feet of radiation, a three-eighth-inch pipe is ample, and for a house with 1,000 feet of radiation, a half-inch pipe is ample. The object in putting in the one-inch pipe is to have a larger body of water. Never having investigated the single-pipe system, I preferred the double pipe. I do not know that there is anything further that I can say in regard to the system.

MR. DAVIS: How much did it cost per mile of pipe laid.

Mr. Copeland: I have not quite the average. It cost $29,000 to put in the 33,000 feet of pipe.

Mr. Davis: I understand that your revenue was $4,600?

Mr. Copeland: Yes; from thirty-nine customers.

Mr. Davis: And the coal cost $2,500? What allowance did you make for depreciation?

Mr. Copeland: I did not make any; we keep our station up.

Mr. Davis: Did you charge that against your steam-plant cost?

Mr. Copeland: The depreciation?

Mr. Davis: Yes.

Mr. Copeland: What is the depreciation?

Mr. Davis: I mean by depreciation the amount practically required to keep the plant in continuous use all the time, and up to the same standard.

Mr. Copeland: That is charged to expenses.

Mr. Davis: Have you had any depreciation yet?

Mr. Copeland: It has not been running a year.

Mr. Davis: No repairs?

Mr. Copeland: Not any.

Mr. Davis: Do you furnish any hot water for baths?

Mr. Copeland: Yes, we did; but they stole it from us. If any of you contemplate putting in hot water for heating, have the air cocks so small that they cannot get the water out of the radiator. We have stolen from us from 800 to 1,500 gallons a day.

Mr. Davis: Could you not make that a source of revenue?

Mr. Copeland: Do that, and you will have to replenish the system every few hours. We allow our customers that wish to do so to take the return pipe, after it has gone through the system in the house, and run it through a coil in a boiler, and it helps out the kitchen boiler a great deal; but, so far as selling hot water is concerned, if you go into that you will be drowned, sure.

MR. DAVIS: What is your charge per thousand units?

MR. COPELAND: We charge by the square foot of radiation. The house is figured for such radiation as will keep the temperature at seventy-two degrees with twenty degrees below zero weather. We started in at fifteen cents per square foot per year. We have now raised the price to eighteen cents. Fifteen cents is not enough in a country so far north as we are. We have to keep up the heat for eight months, and it comes to pretty near eight months' heating.

MR. BAILEY: Do you not think that the interest on your investment will make your operating expenses pretty nearly equal to your income?

MR. COPELAND: I do not. For my thirty-nine customers at $4,600 a year it has cost $2,600 to run it, and there is $2,000 a year profit. Again, I can double the number of customers, heat eighty of them, and receive twice the amount, but I shall not use twice the amount of coal. My other expenses do not increase.

MR. BAILEY: Does the $2,600 include the interest?

MR. COPELAND: No. We have our plant laid for over one hundred customers--125 of them. We can put on that number without making any addition to the plant.

MR. BAILEY: Then you are dependent upon further service to make any money?

MR. FERGUSON: How many heat units to heat 100 square feet.

MR. COPELAND: That depends entirely upon the outside temperature.

Mr. Ferguson: Have you found any trouble with scale?

Mr. Copeland: None whatever.

Mr. Ferguson: How do you prevent it?

Mr. Copeland: We run back into an open tank, and do not discover any. We use the same water all the time; so if there were any scale it would be noticeable.

Mr. Hale: What is the relation of the radiation to the cubic contents of a room?

Mr. Copeland: About one foot of radiation to fifty or seventy-five feet of space, according to construction of building.

Mr. Hale: Has this hot-water system ever been used in connection with condensing plants?

Mr. Copeland: Yes; my plant was condensing.

Mr. Hale: Do you run it condensing when you heat the water?

Mr. Copeland: We run one-half condensing and the other half non-condensing.

Mr. Hale: It seems to me that if you have steam enough you can run it all condensing if your water goes out at about 110°.

Mr. Copeland: It is according to the temperature out of doors; sometimes we put it out at 222°. You can heat the water as hot as you wish, as hot as steam; but it cannot go into steam, because it is confined. Two hundred degrees is usually as hot as it is necessary to put it out.

Mr. Hammond: Hot-water heating plants often run over 100°.

Mr. Copeland: We put it out according to the temperature out doors. At zero we should put the water out at about 180°; at ten degrees above zero we drop to 170°; twenty degrees above zero, nearly the same; and we drop gradually.

MR. HAMMOND: Would it not be the better way to run the vacuum as low as you can and still keep the temperature up to the required point?

MR. COPELAND: No; it is policy to run a little above what is required. We insist on putting on a thermostat or controlling valve that will shut the water off when the temperature in the building rises above seventy-two degrees; and in that way your pump has not nearly the amount of work to do. If you had the temperature of water to keep it up to seventy-two only, you would pump continually. The hotter you send the water out, the less work your pump will have to do.

MR. HAMMOND: Can you heat a building with the number of square feet of radiation that is usually provided by steam heat?

MR. COPELAND: It requires about fifty per cent more than steam.

MR. HAMMOND: This is the two-pipe system, I understand. Is it possible to connect on to the single-pipe steam-heating system with hot water?

MR. COPELAND: No, you must have the return pipe.

MR. HAMMOND: About the profit of this: you say your receipts are $4,700 and expenses for coal $2,400?

MR. COPELAND: No; $4,600 and $2,500.

MR. HAMMOND: About $40,000 invested?

MR. COPELAND: Thirty thousand dollars.

MR. HAMMOND: Allowing ten per cent for depreciation and interest, you have $3,000, which would leave a deficit of $1,000?

MR. COPELAND: You must remember that we have a plant capable of taking care of ten thousand to fifteen thousand dollars' worth of business, and have not to increase the investment to do this business. We make no taps on the mains; it is all done by laterals. The mains are in the streets, and the laterals in the alleys.

MR. BEAN: What is the price of coal?

MR. COPELAND: Illinois coal at $3.70; Youghiogheny, $4.40.

MR. BEAN: Does the water cost anything?

MR. COPELAND: We use some water free, and some we have to pay for. Our average loss in heat is about thirty-five degrees. I want to lose thirty-five degrees, because I want to throw off as much as that into the building. We have not had a single complaint of any kind, and now have contracts for 11,000 feet more to go on, and have the first contract of this kind that the government ever made. We are going to heat the government buildings.

MR. HINE: You consider that this system forms a valuable auxiliary to an electric-lighting plant?

MR. COPELAND: I think it does. But if you take a plant running only at night, one that has no day load, I doubt the advisability of going into it. We have 150 horse power during the day, and it runs up to 550 or 600 horse power at night. The reason we run partly condensing is that the part we run non-condensing is insufficient to heat the water. I am going to try an experiment, and if it is successful I will let you know about it; if not, I shall not say anything about it. This is, in our auxiliary boilers, to heat the water, I am going to put in an induced draft from my steam boilers, and take the gases through the two boilers; as you may call it, an economizer, and I think we can furnish sufficient except in the extremely cold weather.

MR. FERGUSON: How much does it cost to equip a ten-room house; and do you have any difficulty in getting the equipment into old houses, or do you depend upon the equipment in new houses?

Mr. Copeland: The owners of a great many old houses are putting it in, and we are furnishing it for those that did not have their hot-water heating plant in the house. They put a valve between the boiler and the outgoing pipe, and run outgoing water in above the valve and tap the boiler for the return.

Mr. Ferguson: How about the house with the hot-air system?

Mr. Copeland: They throw it away.

Mr. Ferguson: How much does it cost to put in the equipment?

Mr. Copeland: At present prices a house can be equipped for sixty cents a square foot of radiation for the hot-water system. It does not cost so much as the gravity system, for the reason that the pipes can be smaller.

Mr. Scovil: Will you not have to confine your services entirely to residences?

Mr. Copeland: Not entirely; but the bulk of our service is to residences. We have supplied several store buildings, and it has been more than satisfactory in them. They have had to keep the water shut off more than half the time. We feared in the beginning that we were not going to be able to heat them satisfactorily. I worried about it, and went south so as to get out of the way. When I got back I found that the service was more than satisfactory. We have probably thirty residences as customers.

Mr. Scovil: What is the pressure on the pipe?

Mr. Copeland: Forty-five pounds.

Mr. Scovil: You carry that to the top floor of a five-story building?

Mr. Copeland: Yes, sir.

Mr. Scovil: Could you carry it higher than that?

Mr. Copeland: No; that makes about a four to five-pound pressure on the upper radiators on the fifth floor.

Mr. Gilchrist: Have you had any experience in furnishing heat for cooking purposes, in hotels; and is it satisfactory?

Mr. Copeland: Not with water.

Mr. Gilchrist: I mean for their steam-heating apparatus; the steam table, where the food is kept warm; hot water is applicable to that.

Mr. Copeland: No; none at all. We have no hotels on our system. There is one hotel talking about putting it in if we can make it pretty cheap to them.

Mr. Ferguson: Do your customers consider this cheaper than burning coal? It would seem to me that it figures the same, or substantially so.

Mr. Copeland: We do not claim that we can do it more cheaply than a householder can heat the house for himself. We keep the heat on for twenty-four hours a day, and a person running his own plant will not do that. If it is too cold, they will shut up a part of the house.

Mr. Scovil: Do you have any trouble with the reducing valves?

Mr. Copeland: We have no reducing valves; we have the same pressure all over.

Mr. Scovil: How do you protect your pipes and mains in the street; and what provision do you make for repairs when they become necessary?

Mr. Copeland: We laid our pipe in a double box, made of hemlock lumber, with two air spaces.

We put around the main, for experiment, ordinary mineral wool next to the pipe, on the inside box. The inside box is about half an inch larger than the couplings on the pipe. Then, the sides and top are put on perfectly tight, and over that I put asbestos paper, which will shed water and not rot. I laid that over the top and down the sides, and then covered it. Of course, there is a portion of the mineral wool, after it gets wet, that is apt to rust a little, but it will soon dry out. We have a sandy soil, and the water will disappear out of a hole as fast as you can put it in; and I have every reason to believe that the box will remain dry. We have had no trouble with our expansion joints. We put them every block, using the regular brass sleeve joint on all pipes down to four-inch, and on the four-inch we make a loop and drop it down, and it proves very satisfactory.

MR. FERGUSON: Do you make a contract for the entire house?

MR. COPELAND: The entire house; we will not figure on a house unless we furnish the whole house. We have lots of chances to heat less than the entire house. They will say there are two or three rooms that they do not use; all they want heated is the rest of the house. We will charge as much for the rest of the house as for the entire house; because the intention of the person is to heat the whole of the house from your service. If the customer has the right of radiation in the whole house your water is not going through there to exceed one-fifth of the time. If you heat half of it the water is going through there as much as the pipe will let it, continually.

MR. BEAN: Do you wish to go on record as saying that your plant made $2,000, net, last year?

Mr. Copeland: Yes, sir.

Mr. Bean: On the municipal ownership idea? I understand Mr. Copeland to say that he has a plant taking in, gross, about $4,600, and expenses about $2,600; making a net income of about $2,000 on an investment of about $29,000. There is no interest on the investment, nothing allowed for deterioration. Is that a fact?

Mr. Copeland: Yes, sir.

Mr. Neal: There is a city in Massachusetts where there are certain houses warmed by steam direct from boilers from a gas company; and I understand that, although it has been running many years, it has only just paid expenses, and I am inclined to think that if the question of installing that steam-heating apparatus were considered now, they would not put it in. There is one general objection to these plants of which this gentleman has not spoken, and it is a singular objection, too. The mains, in running through the streets, warm the surface of the street so that it melts the snow and injures the sleighing.

Mr. Copeland: It does not injure our sleighing at La Crosse, Wisconsin; a year ago last winter the ground froze nine feet down.

Mr. Bean: How deep are your pipes laid?

Mr. Copeland: Three feet.

The President: Gentlemen, we will now hear the paper by Mr. W. L. Abbott, of Chicago, on central station economies.

Mr. Abbott presented the paper, as follows:

OPERATING ECONOMIES IN CENTRAL STATION PRACTICE

In every central station there grows up a characteristic system of practices, good, bad or indifferent, due partially to peculiar environments and partially to the ability of the operating force. Through natural selection, the best of these practices are gradually crystallized and become the unwritten code of rules for the direction of the internal affairs of the station. Some of these practices, while the very best for that station in which they originate, may prove very unsatisfactory when transplanted into other stations, yet it is largely due to the cordiality with which central-station managers impart to, and adopt on trial from, each other new methods that the present rapid improvements in operating details are being made.

It is in the hope that some of the methods hereinafter outlined may be new and feasible in other places that these suggestions are offered.

OIL AND WASTE

The saving and renovating of waste and oil is an ever-present and variously-handled question in all stations. Some simply use the waste until it is oil-soaked and then burn it under the boilers; others go to the other extreme and use wiping towels, which are carefully saved, washed and used over again. We favor a middle course; using a good quality of waste, first on the finer parts of the machinery, and then for coarser work, after which it is put through a washer, consisting of a train of rolls over which hot water is running. This extracts nearly all of the oil and much of the dirt. The oil and water are caught in a receptacle, the oil is separated and passed to the oil purifier and the waste put into the drier. This drier consists of a sheet-iron box, thirty inches square and six feet high, filled with shelves, one above another, made of wire netting, and spaced about ten inches apart, for the reception of waste to be dried. The case stands a few inches from the floor, and in the bottom, which is open, is a steam coil. A door occupies one full side, and to the top is connected an eight-inch galvanized-iron pipe leading to the boiler breeching, for the purpose of inducing a draft. The whole thing is quite simple and inexpensive, yet it will thoroughly dry a charge of 200 pounds of damp waste in a few hours. This dry waste is somewhat harsh and knotty, but has better absorbing qualities than new waste, and we use and wash it over and over again. In practice, the oilers are allowed but three-quarters of a pound of new waste on a shift, to keep a 1,200-horse-power engine clean, but they are allowed all of the washed waste they want.

In separating oil from waste it is difficult to say which is the by-product and which the direct product, as from 100 pounds of oily waste we get forty pounds each of oil and waste, and one product is about as valuable as the other.

The amount of engine oil used at our Harrison-street station has been reduced to the lowest possible minimum, I think, as it amounts to only about fifty gallons of new oil each month. This is obtained by catching and re-refining all the lubricating oil used on our machinery; which is quite readily possible on vertical engines. The drains from our crank-pits are carried down into the oil refiners, and the oil from the waste is all saved and put through a process that makes it better than new oil. This may sound like an exaggerated statement, but I will explain later on why it is better than new oil. I have spoken of oil refiners and of refining the oil, instead of filters and filtering the oil, for the reason that we have no filters and do no filtering, but purify the oil by settling and boiling. Our filters consist, essentially, of three tanks, as shown in Figure 1, the first of which receives the oil from the engines mixed with cylinder drips, water from journals, etc. When this enters the first tank, which is, say, half-full of water and half-full of oil, the water and oil separate; the water goes to the bottom, where it is drawn off through a trap; the oil goes to the top and is drawn off through an overflow. From the first tank the oil flows to a second tank, in which is a steam coil under a pressure of, approximately, 100 pounds. This is for the purpose of heating the oil up to about 250°, at

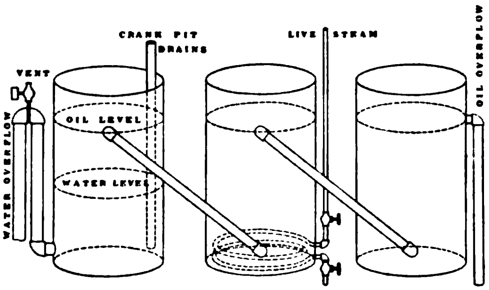

FIG. 1.

which temperature the water is driven off in the form of steam. Owing to the surface tension of the oil around the small globules of water that is held in suspension with it, the water will not vaporize at a lower temperature. This tank is of such a capacity that the oil is about two days in passing through it. From the second tank, the oil goes into the third tank, where it is allowed to stand about the same length of time, and where any sediment it may contain will be deposited. From the third tank the oil overflows into a large storage tank, where it is kept until it is drawn off to be used. Few of those who have not looked into the matter would realize how much water will be absorbed and held in suspension by oil that contains a small trace of animal matter, and how difficult it is to break up the combination, once it is formed. Those of you who operate oil filters may have sometimes wondered at the accumulation of grease in them; this grease being a soft, jelly-like substance, of the consistency of warm lard, or perhaps even thicker. This grease is no more than a combination of mineral oil, a small trace of animal oil and about forty per cent water; and if it were placed in a vessel and heated up to about 250°, the water would be driven off, perhaps with explosive force if heated too rapidly; but if the work is carefully done the water can be separated, and what is left will be the best kind of lubricating oil, containing a small trace of animal oil, and in our case all the cylinder oil from which the animal oil is derived. It is the mixture of the cylinder oil with the engine oil that gives it its heavier body and better lubricating qualities. The oil that is expressed or washed out from the waste apparently contains more cylinder oil than that which comes from the engine drains; and on this account, those who throw away their waste, not only lose the waste, but the richest part of the oil, which is contained in it. That this amount is considerable will be seen from the fact that from every 100 pounds of oily waste we get about forty pounds of clean waste and forty pounds of oil.

CYLINDER LUBRICATION.

The question of cylinder lubrication was once a very perplexing one for us, but after studying and experimenting, we settled the question in such a way that it has not been open for several years. We had great trouble with cylinder oil, and had difficulty in finding an oil that would lubricate all of the cylinders of our triple-expansion engines from one lubricator. We have not found such an oil and do not expect to. We could find an oil that would lubricate the high-pressure cylinder, and we could find an oil that would lubricate the low-pressure; but we could not find a combination that would lubricate all of the cylinders perfectly. We have, therefore, adopted an oil that will lubricate the high-pressure cylinder excellently, the intermediate moderately well, while the low-pressure shows only a slight trace of oil; but as there is no cutting or scratching in the low-pressure while it runs dry, and as the high-pressure cylinder makes a prompt and vigorous protest if allowed to run dry for a few moments only, we have adopted the oil that will give the best results in the high, and let the low be content with what it gets.

The results of our experiments have convinced us that the only oil to use in a non-jacketed cylinder, where it would come in contact with very wet steam, is one that is very highly compounded. It must also be an oil of a high fire test; and the reason why it does not lubricate the low-pressure cylinder as well as the high, in our opinion, is that the temperature of the steam in the low-pressure cylinder is so low that the oil will not remain atomized in the steam, but washes down and combines with the water of condensation that has formed in the other two cylinders, and passes through the low in an emulsion with the water. To prove this theory, I have tried the plan of mixing a cylinder oil of a high grade and high flash test with a light oil of low flash test, and feeding it through one lubricator through all three of the cylinders. The result shows a fair trace of oil on the walls of the low-pressure cylinder, and we ran our engine with this kind of cylinder lubrication for several months, but finally decided that the best results for the entire engine were obtained with that oil which gave the best lubrication in the first cylinder. We now use a heavily compounded high fire-test oil, fed into the steam pipe near the throttle. We find that a gallon of oil thus fed will give good lubrication for a 1,200 horse-power engine for twelve hours. I have seen a compound engine of this capacity fed at the rate of nearly a gallon an hour without obtaining satisfactory lubrication, the whole trouble lying in the fact that the oil was not adapted to the particular conditions under which the engine was working; and I think this may account for the unmeasured praise or unstinted abuse that different brands of good oil receive from different engineers. I think, furthermore, that the difference between a good oil and a poor oil made from high fire-test stock lies almost wholly in the amount and kind of compounding.

In arranging the operating force and the pay-roll of the central station, the superintendent should aim, as in all other matters, to get the maximum of results, and still keep everything harmonious, with the least expenditure of money. To do this, he should carefully arrange his force so that he will at all times have men enough to take care of the amount of work on hand, and at no time have a surplus of help over what is required to take care of the work to be done. This scale of wages should also be carefully graded so that operatives doing the same class of work should receive the same pay, and that the rate of pay to the different classes of workmen should be in proportion to the skill, responsibility or manual labor required. Further than this, a considerable saving in money can be made by paying the operatives partially in hopes and promises. By this, I mean there should be a well-defined and well-known line of promotion, and each one should know his position in that line, and that his chances for promotion depend upon his ability, fidelity and length of time in the service. Any really good, ambitious young man is ready to begin work at the bottom of the ladder, and will work along contentedly on small wages if he is assured that the promotions to come will be awarded upon the above terms, and not by favoritism. The most demoralizing and disorganizing practice that can be introduced into a central station is to put a new man, the relative of some official, or the friend of some politician, into a desirable position over the heads of equally good men who have borne the drudgery and hard work of inferior positions, hoping and expecting that when there was a vacancy in a better position they would have the preference.

In many stations the force is divided into a night gang and a day gang, the day gang going off as the night gang comes on, and *vice versa.* I do not know that this practice is as general now as it was formerly, but I never thought it was well adapted to central-station work. In the first place, the hours are too long, and in the next place it does not give the best distribution of labor. The number of men in the station does not vary according to the load. The practice which we instituted several years ago, of bringing the men on one or more at a time an hour or so apart, and letting them off in the same way, we find can be made to meet exactly the requirements of an uneven load, and it enables us to rotate the different men of the same class through all the different shifts during the course of one or two months, thus making the work and the hours of all exactly alike in the cycle. At the end of each week the schedule is made up for the week to come, for each of the different classes of operatives interested, and this is posted on Saturday night, so that as the men go off work on the following Sunday it is known what shift each will have during the coming week. These schedules are altered from week to week, increased or diminished as regards the number of men, and changed in form to conform to the varying conditions of the load curve.

To illustrate by a set of December schedules: The problem to be solved is to arrange the schedules so that there will be at any time enough men for the work, without having too many men around at other times, and, furthermore, to arrange the shifts so that none will be obliged to go home between the hours of one and six in the morning.

As we are not sure what the load will be from day to day, or a week ahead, we are obliged to provide men enough to take care of what we assume will be the reasonable maximum. It is, of course, impossible to meet the requirements exactly without breaking a man in two and using the pieces in non-consecutive times of the day; but with a little care and study it is possible to arrange the schedule to meet very nearly the exact requirements. Take, for example, the firemen's schedule for the week commencing December 18th, 1899, as shown in Figure 2

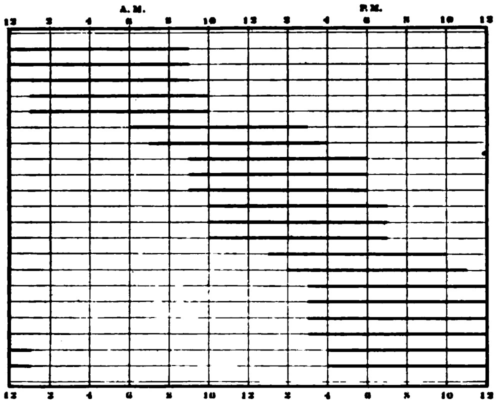

FIG. 2.

We start at midnight with five firemen; two of these are relieved at one o'clock by two other men who come on at that time. As the load from midnight until six o'clock is quite irregular, owing to the variable amount of charge required by the battery from day to day, we have rather more firemen on during this period for the amount of work done than we have during other times of the day. At six o'clock in the morning the load begins to pick up, and has nearly reached its morning maximum by nine o'clock. To take care of this our force of firemen is increased by one man each at six, seven and eight o'clock, there being by that time eight men on; and the force is held at that number until one o'clock in the afternoon. During this time several men come on and others leave, but the number at work remains the same. The slight drop of the load at noon is not followed by a corresponding change in the number of men, but it is taken advantage of as a slight breathing spell, and gives the men an opportunity to clean fires and eat their dinners. After the midday drop in the load there follows a gradual rise until four o'clock, which we anticipate by bringing a man on at one and another on at two; at four o'clock the load rises abruptly to the maximum shortly before five. We provide for this by bringing three men out at three o'clock to get their fires in good shape, ready for this hard pull; and, finally, at four o'clock the last man comes, which brings the total number of firemen on at this time of the day up to fourteen men. After five

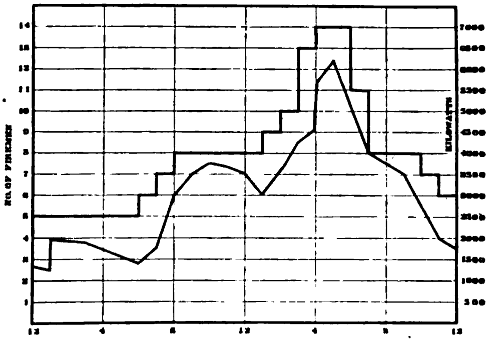

FIG. 3.

o'clock, the load gradually declines until midnight, when it is only about one-fourth as high as it was at five. Owing to the way in which the men have been brought out, their shifts are finished so that the force is automatically decreased in proportion as the load decreases, and we have during the day worked twenty-one firemen, who have altogether burned about 210 tons of coal, and have been so distributed that we have at all times had an excess of one or more men for the work, and none have been overworked. Figure 3 shows the load curve for December 21st and also what we may term the firemen curve for the same day, which shows at a glance how nearly the size of the firing crew was adapted to the requirements.

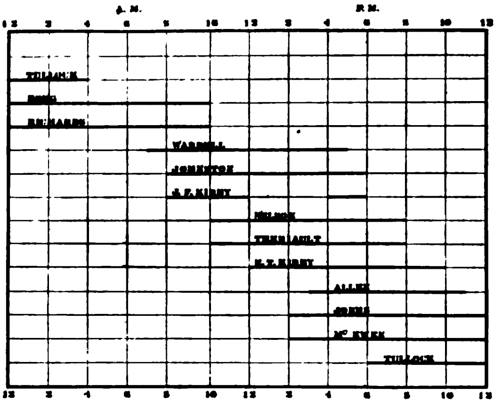

FIG. 4.

Figure 4 shows the oilers' schedule for the same week, and Figure 5 shows how nearly the number of oilers were proportioned to the amount of work to be done on December 21st.

The greatest possibilities for saving or wasting about a steam plant are undoubtedly in the coal pile; but as it is a dirty proposition and many of its features are not well understood, the subject does not receive the consideration to which it is entitled.

The average ambitious engineer will spend much time and care on his engine to be sure that the indicator cards are perfectly symmetrical, that the points of cut off are equal, that the release is in time, and that the compression rises to meet the admission in a smooth, rounded curve. This is proper and commendable, yet the same time spent in studying the conditions of combustion in his furnace might show him a way to make a saving in fuel fourfold greater than is possible in the final refinements of the indicator cards.

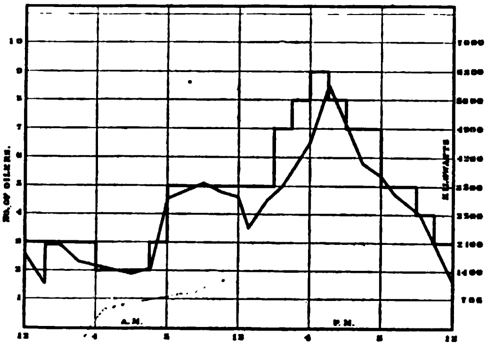

FIG. 5.

A fireman whose wages amount to, say, twenty cents an hour will burn during that time fuel costing ten or fifteen times as much as his wages. It would not be possible by any sort of driving to save half of the wages, but it is readily possible, by properly watching and instructing the fireman, to save double his wages in coal. In the first place, great care should be exercised in the selection of the coal to be used. I believe that the cheapest coal is that kind which has the greatest amount of combustible for the least amount of money, provided the furnaces are of the proper kind and ample in capacity to make the required amount of steam from them. The very cheapest kind of Illinois screenings, costing less than $1.50 a ton, will not have less than 10,000 British thermal units a pound, and the very best of eastern lump, costing $4 a ton, will not have more than 14,000 British thermal units a pound. This means, then, that for equivalent heating qualities the cheapest screenings cost about half as much as the high-grade coal.

Having selected the coal, the next problem is how to burn it properly. It is commonly understood that twelve pounds of air are needed to burn one pound of coal properly. It is also commonly supposed that in practice about twice this amount of air passes through the fire, but just how much actually passes and under what conditions the best results are obtained are impossible to determine without making analyses of the flue gases. Fortunately, this has now become a very simple operation, and one that can be performed and understood by anyone competent to take charge of a large boiler room. These tests often show the most surprising and disappointing results. The analyses are made to determine the percentage of carbon dioxide in the flue gases. Under perfect conditions it can run as high as twenty per cent, but it is not unusual to find samples running as low as two per cent of dioxide. This brings down the economy, for two reasons: First, the gas in the firebox is diluted with an excess of cold air and cooled down; and, secondly, the amount of gas, being increased in volume, passes through the boiler more rapidly and does not give up so much of its heat. It is almost a paradox that, within reasonable limits, the more the gases are cooled down in the furnace by the admission of excess of air, the hotter they will pass away from the boiler. The two causes of excess of air in the flue gases are, first, running boilers on too light loads, and, secondly, careless firing.

In a station where the load is much higher for a few hours than during the rest of the day. the tendency is to have too many boilers in service during the period of light load. The natural result is that the fires are run thin; the grates get bare in places, and a great volume of air is drawn in, and only a small portion of it comes in contact with the fuel.

Careless firing is always a flagrant waste of fuel. An engineer may be aware that he is not getting the results that his tests lead him to believe he should have, and yet in a boiler room where several men are working it is exceedingly difficult to fasten the blame on any one of them unless one can examine the chips the men make, or in other words the flue gases.

To follow intelligently the work of the individual fireman, we have installed in our boiler room a device called the econometer, through which is induced a small current of gas from a boiler breeching. The weight of this gas, changing with its composition, moves a pointer across a dial, thereby indicating continuously the varying percentage of carbon dioxide in the flue gas. From this device are run individual pipes to the breeching of each boiler, and all is so arranged that samples may be drawn from several boilers and tested in a few minutes, or a continuous test may be made of the performance of any one boiler.

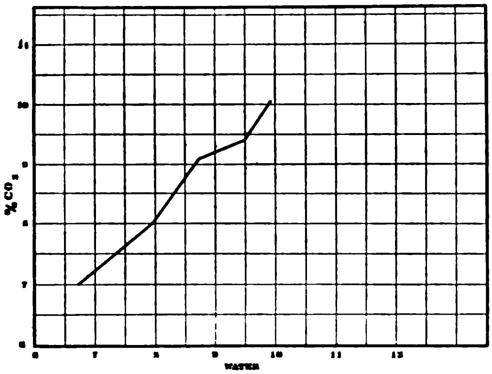

FIG. 6.

Readings taken from this instrument at regular and short intervals, when plotted, form a curve that is a very comprehensive record of the conditions of combustion during the time of observation. A few of such curves I submit herewith: Figure 6 shows

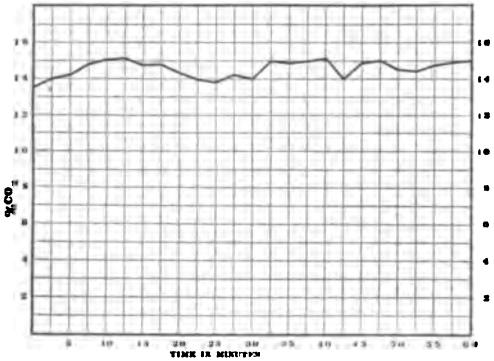

FIG. 7.

the results of a test made to determine the relation between the boiler efficiency and percentage of carbon dioxide. The results show that, within the limits tested, the two are almost directly proportional. Figure 7 shows the results of skillful and even firing. Figure 8 shows the result of careless and uneven firing. Figure 9 shows, first, what occurred when a fire was cleaned in a leisurely manner, the dioxide dropping to one per cent; then followed a charge of

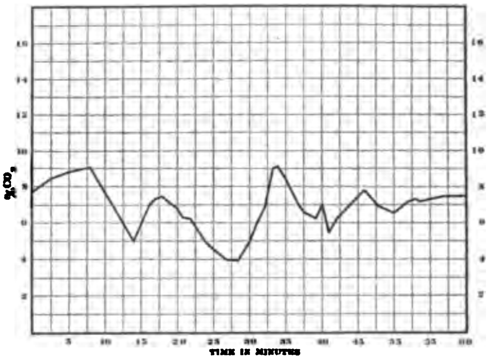

FIG. 8.

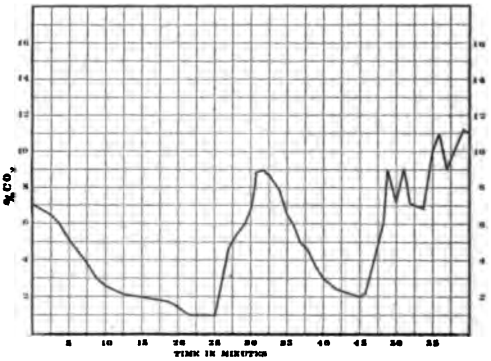

FIG. 9.

coal, which got the furnace in good working condition; but as the fire was not replenished during the next fifteen minutes, it burned so thin that it is

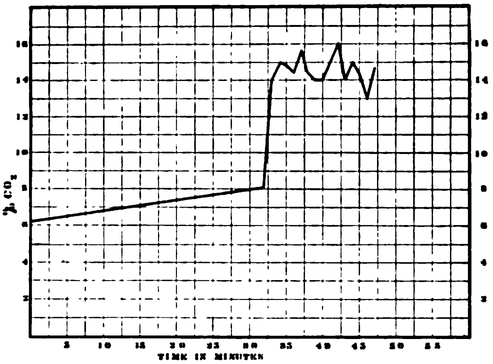

FIG. 10.

doubtful if the boiler was making steam at all. The latter part of the curve shows the automatic improvement in the fireman as soon as he observed that he

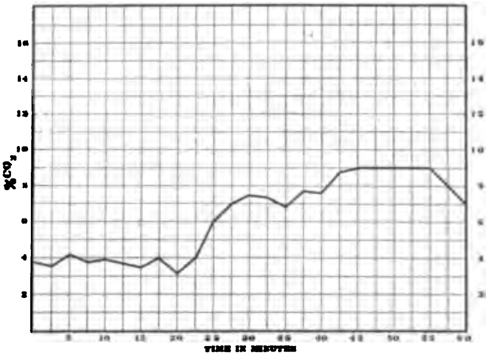

FIG. 11.

was under surveillance. Figures 10 and 11 show how the work of a fireman may be improved by giving him intelligent instruction.

The above are a few of the methods we have adopted for reducing operating costs.

Some of them may appear trivial, but when we consider that $100 saved is $100 added to the surplus, which is as good as a $500 increase in the gross earnings, and that to add $500 monthly to the gross earnings would require an investment of, say, $25,000 —when we consider this, we may realize what a valuable asset is an engineer who is prolific in methods for keeping costs down or is ready to adopt such methods from others.

DISCUSSION.

THE PRESIDENT: Gentlemen, we are ready for any discussion on this question that may be of interest to you.

MR. SCOVIL: I would ask the gentleman if these curves are the result of hand firing?

MR. ABBOTT: They are.

MR. SCOVIL: Have you any curves of firing with automatic stokers?

MR. ABBOTT: No; I have none here.

MR. SCOVIL: What would be your opinion on the question of automatic stokers?

MR. ABBOTT: They show better results than hand firing. They can be made to show any kind of results, but it does not require so much skill to operate an automatic stoker and get good results as it does to get good results in hand firing.

MR. SCOVIL: Why don't you have automatic stokers?

MR. ABBOTT: If you will ask that question in about four months I will answer that we have them.

PROFESSOR GOLDSBOROUGH: There were one or two points brought out by Mr. Abbott that appealed to me very strongly, and I should like to take this opportunity to emphasize them. I presume the men that are engaged in educational work have as good an opportunity to study the attitude of young men toward their work as have men in commercial life; and I think the point of encouraging young men by holding out to them some prospect of advancement is an important one. I believe we can get almost double the efficiency from young men by having them feel that they have an interest in the business—an interest that will bring to them in years to come a really good position. I think this is a fact beyond dispute, and I believe that any one that has tried the method will bear me out in what I say. This belief is more and more emphasized in my mind every year, as I have greater opportunity of observing the success of young men that graduate from our university.

There is another quite important matter to which Mr. Abbott calls attention—the matter of adjusting the number of boilers in a station to the work that the boilers have to perform. I have frequently noticed that one of the prime defects in station management comes from heating up water and boiler iron without getting any return for the coal thus expended; and in a few cases within my experience it has been demonstrated beyond a doubt that several thousand dollars per year were saved by simply giving attention to this one matter of adjusting the boiler capacity to the load upon the station. The other points that Mr. Abbott makes are, I think, very valuable; and the diagrams speak for themselves.

Mr. Doherty: There was one point in which I was particularly interested, and that was the statement that flue gases could be easily tested and analyzed. In about one hundred central stations with which I am familiar, there is not one in which they make an analysis of flue gases at regular intervals, and if they ever analyze them at all, it is a very unusual thing. I should like to see some of the members of this association put on a committee to tell us how to operate boilers and analyze the flue gases. In one plant with which I am acquainted the flue gas is analyzed by the firemen, or, at least, determinations are made for carbon dioxide, and from that other conditions may be safely assumed. I am not familiar with their exact method, but in general it is simply that they draw a certain portion of their flue gas and pass it through an alkaline solution, which absorbs the carbon dioxide, and the difference in volume before and after this treatment represents the amount of carbonic-acid gas that was present. I have not seen the econometer of which Mr. Abbott speaks, but have for several years adopted an old gravity balance, which I have used for that purpose, and I intend going a little further and making it a recording instrument, and hope to have it ready in a few weeks.

The greatest trouble that I find with most central-station managers is that they take up the losses in the central station in the order of their apparent importance rather than in the order of their actual importance. In the smallest central stations I doubt if any great effort ought to be made to economize in the matter of oil and waste; it often forms an almost insignificant item. Boiler fuel has always been believed to be the most important thing in which we should economize, and it certainly represents the biggest part of our actual operating expenses, and

Mr. Abbott, in calling special attention to the boiler results, not engine results, has done a service to the entire electrical fraternity. The amount of saving that engineers can make on engines is small compared with the amount of saving that can be made on the boilers. Where no effort is made to determine the efficiency of the average boiler, it is apt to run below forty per cent; but with such a load-curve as Mr. Abbott enjoys, he should be able to get a boiler efficiency of over seventy per cent. His statement that the coal having the greatest heating value per financial unit of value should be selected, is a point on which I can hardly agree with him. I think he must go back and take that class of coal that will give the greatest amount of steam for a given financial value; and I have found that you can not make a calorimeter test of your coal and be sure that you are going to get the same volume of heat; that is, that you are going to transfer a given percentage into useful heat. Many coals that are not high in quantity of heating value, are much higher in their efficiency, because you get a much higher flame temperature and produce a great activity in your furnace, which enables you to reduce your over-ventilation. Mr. Abbott did well when he tried to impress on the members the great source of loss in over-ventilation. If just the correct amount of air could be used, so that the gases could have contact with it without absorbing the surplus of it, we could probably increase their temperature considerably. Over-ventilation is the paradox to which Mr. Abbott refers, of having a lower temperature in the fire box and a higher temperature in the chimney, which is due to the increased velocity of the gases passing through the flues, and hence less time for the absorption of heat.

Professor Jackson: Mr. Abbott's paper certainly points out a most fertile field in which the small stations can improve in the station operating expenses. I have seen the results of operating in a great many of the smaller stations, and, of course, it is the smaller stations that make up the majority of stations in the country.

Mr. Abbott handles a large station, and his conditions are different from those of the average station. But even in a small station a reasonably good fireman can readily get eight per cent of carbon dioxide in his flue gas; he ought to do so; yet I am safe in saying that probably the average of the stations will not reach five per cent; some do not reach two per cent. That is due to the fact that the fireman does not know these things that Mr. Abbott recites, and the station managers have not recognized the advantage of coaching their firemen.. A large amount of money can be lost between the coal pile and the furnaces. That is the point that Mr. Abbott has raised. If the coal is put into the furnace with the proper proportion of air, and in the proper manner, with sufficient uniformity, a great saving can be effected.

In regard to automatic mechanical stokers, they ought to do better work than hand firing, except that hand firing which is done in the most careful manner, which no human organism can keep up through an eight-hour shift. On the other hand, I have seen small plants, with 1,000 horse power or less, with automatic stokers, where the flue-gas analysis showed not more than two per cent of carbon dioxide. (I am not prepared to speak in regard to the larger plants.) The fireman does not expect to work hard in the plant with mechanical stokers, and will sit down and read the papers, and let the fire burn low. Even if they have to feed into the stokers from overhead storage of coal, which involves a minimum of labor, the firemen will not take care of the feeding of the coal in such a way that it is uniform unless they are carefully supervised; and it is not an unusual thing to find less than five per cent of carbon dioxide in the flue gases of plants using automatic stokers where careful supervision is not exercised. It must be understood that plants using less, perhaps, than fifty tons of coal per week are not likely to find mechanical stokers of economy.

The fuel is a large lump in the total operating expenditures. Consequently, if by increasing our carbon dioxide from five per cent on an average to eight per cent, or a little better, we can save from ten to twenty per cent, or, perhaps, even more of the coal used, it means the difference between getting along on our uppers, on the one hand, and having a goodly sum of money at the end of each year, on the other hand. This very point is one, according to my experience, to which the central-station managers have given entirely too little attention. They go into the transformer question with great care, and the distribution question is given great attention—justly so—also the engines, and even the pumps; but the station manager ends there, as a rule, and lets the firemen go their own gait.

The fact is that flue-gases can be analyzed very readily, even though the automatic device spoken of by Mr. Abbott be not used. There are types of flue-gas apparatus that can be used very readily by any good intelligent station superintendent who has been given a little instruction. Of course these are not continuous in their record; they do not show the record all the time. They are of the type by means of which samples of flue gases gathered now and then may be analyzed. Such devices are excellent, but are not so good as a device that shows the record continuously, because with the record always before him the fireman will do his best at all times. I am certain that the point Mr. Abbott brings up is, for the central-station manager, one of the most important that can be considered at the present time.

MR. CAHOON: I should like to know how you analyze these gases. I think many of the small-station managers would be glad if you would give them a little detail in regard to your method of analysis.

MR. ABBOTT: I think that Mr. A. Bement, who is present, could tell us more about it than any one else.

MR. BEMENT: We ascertain conditions, with the instrument mentioned by Mr. Abbott, in the following manner: If the conditions prevailing are those of a thin fire or a strong draft, and the indication of carbon dioxide shown by the econometer is low, it is an indication of an excess of air. If, on the other hand, the fire is thick or the draft low, and the indication is low, it is proof of incomplete combustion. The reasons are that in the first case the total volume of gases is increased, owing to the large amount of air present that is not used, causing the carbon dioxide to be small in amount in relation to the total volume; second, the carbon dioxide is less with incomplete combustion, because carbon goes to carbon monoxide instead of carbon dioxide. If the indications of the instrument are irregular, it shows an uneven condition, which may be, and usually is, accompanied by both an excess of air and incomplete combustion. If the highest carbon dioxide obtainable in a furnace is fifteen per cent, and the instrument indicates less than this, it is apparent that something is wrong, and any change in firing conditions is immediately and automatically indicated.

MR. DOHERTY: How about the chemical analysis?

MR. BEMENT: For a chemical analysis we use the absorbing econometer, the Orsatt apparatus,—a modified or improved form of the Orsatt—which I consider has some advantages. I have also used a method by which it was possible to gather a gas sample and make analysis for carbon dioxide and carbon monoxide at two-minute intervals. I found, however, that the method, which is excellent where there is a little oxygen present, is not satisfactory when oxygen exceeds about three per cent. The absorbing econometer is a very simple instrument; it is used for carbon dioxide determination, and is employed where the gravity instrument is not available. The gas is pumped into a measuring and absorbing chamber, where it is confined, and by the movement of a partition the gas is brought in contact with the reagent, and the reduction in volume is indicated on a graduated tube by a water column at atmospheric pressure. This is the most rapid of all chemical instruments. I have been able, by its use, to determine carbon dioxide at one-minute intervals, while riding on the front end of a locomotive, and also to make seventy-five analyses and seventy-five observations of temperature of escaping gases, and make a record of each in seventy-five minutes.

MR. DOHERTY: I understand, then, you only make that analysis for carbon dioxide, and do not make an analysis for either oxygen or carbon monoxide?

MR. BEMENT: Usually, yes. The carbon dioxide determination is so easily and rapidly obtained that it is more useful than more elaborate analysis.

MR. DOHERTY: I agree that you can make an analysis of carbon dioxide that will give a good indication of the results you are getting, but as over-ventilation or under-ventilation will both reduce your gravity, you cannot be certain unless you analyze them free of oxygen and carbon monoxide; and I thought possibly you had some simple method whereby these determinations can be readily made. Even if the determinations are made only periodically, and constant determinations made by means of gravity, there is no reason why we cannot get very much better results.

MR. BEMENT: We always employ the more elaborate methods of analysis where it appears that such are the best means to obtain the desired information; and these investigations would not be confined to the two carbon oxides and oxygen if there were occasion to go further, but would be extended to hydrogen and hydro-carbon compounds. The only rapid method of determining carbon monoxide, of which I am aware, is that which I employ. It is very expensive, and rather difficult; the cost of the apparatus was about two hundred dollars, and while very interesting, I consider that it can have no industrial application. The simplest methods are always to be desired, and if such give the best results, they are preferable to more elaborate laboratory methods.

MR. DOHERTY: I have been reading some gas literature, as well as electric-light literature, and often run across something that will prove of interest to others. In the past two or three years, there has been developed in Europe a gas process that is called the Delwick process. Its operating methods somewhat disturb our former theories on the combustion of fuel. They start in with a fuel bed of about three feet eight inches, and they find that by determining the velocity of their blast they can drive air through that three feet eight inches of incandescent fuel and produce more than ninety per cent of carbonic acid gas, which we would theoretically figure. I think that will be apt to surprise any man that confines his work to boiler firing. They have demonstrated time and time again that with forty-four inches of incandescent fuel they can, by regulating their blast, produce nearly the theoretical amount of carbon dioxide. I have waited for some one to apply this discovery to boiler firing. I have discussed this matter with one or two steam engineers, and the first point that suggested itself to them was, how you could regulate the heat for the amount of steam you were to produce, and regulate the draft. I offer this solution,—but possibly some engineer can offer a better—which is, regulate the furnace as they now regulate the Parsons steam turbine; instead of a continuous blast, have an intermediate blast.

I do not know whether any one here has had occasion to examine the results of the Delwick process, but if they want to look the question up, they will find the process recorded in *Journal of Gas Lighting*, London, England; *Progressive Age*, New York, or *The American Gas Light Journal.* There is no question but that they have obtained results with this system that have never been equaled in boiler firing.

I move that a committee be appointed to determine the best methods for analyzing flue gases.

The motion was put and carried.

THE PRESIDENT: I will appoint that committee later, after consulting with some of these gentlemen. Are there any further remarks on this subject?

MR. ABBOTT: I think that if Mr. Doherty gets his apparatus for analyzing flue gases in operation before the committee makes its final report, there will be no question but that it will be the apparatus recommended; for I can not think of any device that would be more useful, or more readily applied in any steam plant, than such a means of keeping tab on the fireman. The recording steam gauge is a great thing, but if we had a device that would check up the efficiency of the fireman as well as the pressure, there would be no steam plant that would be without it. The average plant, which will burn $500 worth of coal in a month, could, by such a device, save not less than twenty per cent of it. One speaker complimented me on the load curve we are able to show, and suggested that we have an efficiency of, possibly, seventy per cent. While I think we have a good efficiency, so far as efficiency goes, speaking candidly, whenever any one asks me what it is, I am ashamed to tell them, because efficiencies are so little understood; the actual results that you get in twenty-four hours are so little understood that if you should tell any one candidly what the results actually obtained were, they would set you down at once as a very poor manager. I do not think that the average results in the plants throughout the country, as some one suggested, are over forty per cent of the efficiency of the coal. By careful valve setting you might be able to make an improvement of five per cent in the extreme in the results obtained by an engineer; or by judicious selection of transformers, at considerable expense, you might save an equal amount; but there goes on from day to day, unobserved, and without causing any concern, a loss at a place where there is a possibility of saving not less than thirty per cent in many cases, twenty per cent in the average case, which is in the form of fuel consumed and the labor that it costs to handle that fuel. This does not cause any one any anxiety, but if it occurred where they could see it go, as in the case of losing a couple of gallons of oil a day or in the throwing away of a few pounds of dirty waste, it would set the manager to work at once to make a saving. It is a great illustration of the saying, "wasting at the bung-hole and saving at the spigot."

MR. WHITE: This question, while of interest to all large stations, is of particular interest to the great body of members of the association, because they operate small stations. Boilers are operated either with mechanical stokers or by hand firing. The advantage of the mechanical stoker lies very largely in the saving of labor, rather than in the saving of fuel. I believe that for an average of the whole country, skilful hand firing with a properly set boiler will show a better evaporation per pound of coal than the mechanical stoker; and while the saving in labor overbalances — probably overbalances several times over—the extra amount of coal consumed, the small station manager has to recognize the fact that he cannot make a saving in the amount of labor in the boiler room. The amount of labor that will be required in the boiler room of a small station cannot be less than one man, and, no matter what the possible saving will be theoretically, you cannot operate a mechanical stoker with less than one man; so the small station should recognize that it not only can not save in its labor, but that it cannot save in its fuel, by adopting mechanical stokers, and should therefore not consider their use.

The larger stations are able to pay better wages, and usually have better skill, and therefore have better boiler settings, than the small stations. The boiler efficiencies of small stations being lower, the losses due to improper combustion form a greater percentage of the total losses for the small station than for the large station, and for that reason the determination of the amount of carbon dioxide by a mechanical tester, such as has been described, is of particular value, and an important adjunct to the station, assisting to save where the only large station saving can ordinarily be made—in the boiler room. For that reason, I should like to ask, for the benefit of the members of the association, what would be the ordinary cost of an econometer, such as is being used by Mr. Abbott, for the ordinary small station operating one, two or three boilers?

MR. ABBOTT: I think it would be about one hundred and fifty dollars; perhaps one hundred and seventy-five dollars would cover the investment.

THE PRESIDENT: We will now hear the report of the committee on standardization of electrical apparatus.

PROFESSOR ROBB: Professor Crocker, the chairman of the committee, was unable to be present at the meeting, and, as I am the second member on the committee, he has requested me to make the report for him.

REPORT OF COMMITTEE ON STANDARDIZATION OF ELECTRICAL APPARATUS

At the preceding convention of the association, held in New York, May, 1899, Mr. Paul Spencer, of Newark, New Jersey, chairman of the committee on specifications for electrical apparatus, presented a report. This report approved of the work then being carried on by a committee of the American Institute of Electrical Engineers in standardizing apparatus, and recommended that it should be the basis of any similar action on the part of this association so far as technical matters are concerned. Since that time, a final report has been accepted and published by the institute, the classification and rating of the various kinds of electrical apparatus being defined in considerable detail. This report was very well received, and has already been formally approved by most of our prominent manufacturing companies and engineers. Although only published a few months, its recommendations are now commonly recognized and followed. It is generally conceded, even by its critics, that the report is impartial, as well as substantially correct, and that its general adoption will be a great benefit to the many interests affected by it.

Your committee believes that the approval of that report by the National Electric Light Association would be a powerful influence in securing its universal acceptance, and recommends that such action be taken.

The same committee of the institute is now working in cooperation with a committee of the American Society of Mechanical Engineers, to secure a standardization of the sizes, speeds and armature bore of direct-connected engines and dynamos, thus avoiding the confusion that now exists regarding these matters. Considerable progress has already been made, and it is hoped that these committees will be able to secure the much desired uniformity. This is in line with the report already made, and will probably commend itself to the association as being worthy of approval.

Regarding the advisability of preparing standard specifications—a matter that has been discussed before the association several times—there are differences of opinion, and it is well to have the technical questions settled before taking up the commercial ones; but it would appear that the former will be formulated and accepted in the near future, so that the time would be ripe for at least considering the latter. It is wise to go rather slowly in these directions, but it is satisfactory to know that steady advance is being made.

Respectfully submitted,

Committee {
F. B. CROCKER, Chairman,
W. L. ROBB,
J. W. LIEB, JR.

THE PRESIDENT: Gentlemen, you have heard the report of this committee; what action will you take upon the report?

Mr. Cahoon: Mr. President, I have gone over the standardizations made by the committee of the American Institute of Electrical Engineers, and it seems to me they ought to have the approval of this association. They have been adopted by the Institute of Electrical Engineers, and I think we are perfectly safe in following in their footsteps. They are coming into general use by electrical engineers in drawing their specifications, and I know, from my own experience, that they have helped to simplify matters. I therefore move that we approve of these standards and adopt them.

The motion was carried.

(For Report of the Committee on Standardization, of the American Institute of Electrical Engineers, see Appendix.)

The meeting then adjourned.

ORDER OF BUSINESS

Wednesday, May 23d, 1900

THIRD SESSION, 10.30 A. M.

1. Paper: "Uniform Accounting." By James Blake Cahoon

FOURTH SESSION, 2.30 P. M.

1. Paper: "Series Inclosed Alternating Arc-Lighting for Street Lighting Service." By William Lispenard Robb
2. Paper: "Equitable Uniform and Competitive Rates." By Henry L. Doherty

THIRD SESSION

President Carnes called the meeting to order at half past ten.

THE PRESIDENT: The first business this morning is the paper by Mr. James Blake Cahoon, of Syracuse, on uniform accounting.

Mr. Cahoon read the paper, as follows:

UNIFORM ACCOUNTING

First, The Necessity: At each of the conventions for several years past, some mention has been made of the necessity for all electric light and gas companies to pursue a similar method of accounting, but the remarks have been injected into the proceedings in a more or less haphazard way, and even some years ago a committee was appointed to prepare a system of blanks and reports with a view to obtaining uniformity in the preparation of data so that costs could be compared. I have followed this subject with much interest, because it seemed to me that the time was coming when we should be placed on the defensive in the matter of these public utilities, by reason of the growth of feeling for municipal ownership.

At the meeting of the League of American Municipalities, held in Syracuse, New York, September 19th to 22d, 1899, the feeling shown in behalf of municipal ownership was so strong that it startled me. I had been asked to prepare a paper for that convention on the negative side of municipal ownership, and while in attendance there I discussed with many of the prominent men the question of municipal ownership, and, running through the whole discourse, there lay these points, which every one of the thousand members seemed to have at his fingers' ends: Improved service, lower rates, and diffusion of use, of which the main point was lower rates.

Under their system of accounting, or, rather, lack of system of accounting, they were fully convinced of the idea that by the city operating its own plant they could do it from twenty-five to fifty per cent cheaper than the same thing could be furnished by a private ownership. On behalf of this association, I presented to the convention the following letter, stating to them our anxiety to get at the truth of the matter of costs.

136 LIBERTY STREET, NEW YORK,
August 21st, 1899.

LEAGUE OF AMERICAN MUNICIPALITIES,
Syracuse, N. Y.

GENTLEMEN: The National Electric Light Association, appreciating the great importance to the taxpayers of the country of the question of municipal ownership of quasi-public corporations, and understanding that your honorable body, assembled in convention at Syracuse, do propose to discuss thoroughly this very pertinent question, both for and against, and believing it to be of mutual benefit to arrive at facts, does through its officers and executive committee (being the governing power vested with full authority), hereby offer to bear one-half the total expense, said total not to exceed $5,000, of employing a competent expert to examine as many municipal electric light plants as the above sum will permit. The properties to be examined shall be selected by the League of American Municipalities, and said expert shall be selected and appointed by the president of the National Electric Light Association and approved by the president of the league. The result of such examination shall be in the form of a report, sworn to before a notary, in duplicate, one copy of which shall be furnished to the league and one to the association.

If this proposition meets with your approval, the representative of this association by whom this is presented is authorized to make all preliminary arrangements.

Respectfully,

S. T. Carnes, President.
O. T. Crosby, First Vice-President.
J. B. Cahoon, Second Vice-President.
Geo. F. Porter, Secretary.

The league finally adopted a resolution that reads as follows:

Resolved, That the offer of the National Electric Light Association to pay one-half of the expense, not to exceed $5,000, to investigate municipal plants, the investigator to be appointed by said association, be accepted on the following conditions:

First—That the president of the league appoint one investigator and the president of the National Electric Light Association another, these two, with any needed assistants, to investigate jointly and report on all points of agreement and disagreement.

Second—That the investigation be continued to the charges for domestic, commercial and street lighting, the cost of coal, the wages and hours of labor, in private companies whose conditions are as similar as may be to those of the public plants examined. The presidents of the two associations, in conference with their expert investigators, to select the plants to be examined, both public and private. In case of disagreement on this point, half of the public and half of the private plants to be selected by each president.

Third—That in view of the regular dues of the league being inadequate for even ordinary running expenses, the money for this investigation shall be secured by our treasurer from special donations, and our acceptance of the offer under consideration shall be conditional on the raising of this money, for which end we hereby request all those interested to contribute liberally.

Mayor Pierce of Marshalltown, Iowa, and Mayor Smyth of Charlestown, South Carolina, seemed to voice the sentiment of the convention—that if they gave us permission to examine municipal plants with a view to ascertaining the costs of operation, we certainly ought to be willing to permit them to examine our plants to get our figures of costs. The point that our association desired to make was this: That, in the first place, hardly any one of the cities in question operating municipal plants was charging to the cost of operation factors that should enter therein, and, hence, the costs that they were reporting were not true, and they were simply deceiving themselves and the public in the matter of costs.

We proposed that we should take any municipal plants that might be selected, and apply to them the same rules regarding costs of production that a private company would have to apply prior to the payment of dividends. The question immediately came to my mind: Do we as a national association approve of any one system of accounting? Do we all charge the same factors to cost of production prior to declaring dividends? From my experience with various companies, I could say that, in the main, we did; but, at the same time, there are many different ways of getting at this cost of production, practised by as many different companies, and if we undertake to present this matter to the League of American Municipalities, we must unite on a system of accounting that shall be uniform for all similar classes of companies, in both electric-lighting and gas fields.

The reason why I include gas companies in this question is because quite a number of members of this association are not only operating electric-light plants, but are operating gas plants in connection therewith, and in order to cover the subject fully, it is necessary to treat of gas companies as well as electric-light companies.

I doubt if there are in this whole association a dozen members who realize fully the gravity of the present situation for the private ownership of public utilities. The question is taking on a new form. Heretofore franchises have been granted haphazard, and little, if any, effort has been made by the different states to follow out any one line of policy with regard to either the granting of franchises or the operation of companies under those franchises. Massachusetts has taken a step; and a long one, in the direction of what the future will bring about, and that is, the regulation of all public utilities, and the compelling of all such corporations, be they private or municipal, to render to a board of commissioners an account in prescribed form at definite intervals.

We can not take the stand that it is against public policy that this should be done; it would simply be a case of kicking against the pricks. There lie open before us the two paths: Municipal ownership or private ownership under state regulation. We certainly do not want municipal ownership, therefore let us prepare to accede gracefully to the other course; and not only that, but let us help it along. In that lies our salvation.

To do that, we must be prepared, when the question of state regulation is raised, to meet the committee half-way; to say to them, Here is our system of accounting. It is one in which we believe the true costs to be stated; all the factors that enter into the cost are here. We are not a single company using this system; we are one of a great body, all of whom follow the same method and use the same system of accounts in determining their cost of production. We are perfectly willing to hand in once a year a complete statement of everything, costs as well as receipts, and show you gentlemen, and, through you gentlemen, the great public that is behind you, just what legitimate profit there is in this business. It is not great, and we are willing to have you know what it is and how it is computed. We believe that the introduction of electric lights and gas into a city is a public improvement in the strictest sense of the term. We hazard our money, our reputations, and enter on a somewhat venturesome risk; we believe we are entitled to, and we think the public will sustain us in having, a fair return for our labor, our venture, and our capital. We are not only willing that the public should know our profits, but we feel that if the public does know them, it will concede that we are holding the right position; and instead of taking away our franchises, letting competition in on us from all sides, and trying to squeeze us to the wall in every way, it will realize that we are what we claim to be, a public improvement, and that we deserve fair treatment; and we shall get it.

From a financial point of view, it matters little to this association what system of accounting its individual members may follow. If they are deceiving themselves in regard to costs, we as an association should not be warranted in interfering. We, at most, can only recommend the adoption of any system of accounting; we can not compel our individual members to accept it, but we can at least ask them to do so.

The necessity, therefore, for a system of uniform accounting lies primarily in the fact that we must unite for self-defense, and we must be able to ascertain the true cost of our productions, and at the same time show to the advocates of municipal ownership that, to get the true costs, they must follow our system. In unity only shall we have strength to resist the attack that is coming upon us.

Second, Requirements: The prime object of any system of accounting is that it shall be a true record of all the transactions relating to the business involved during the period of time in question. Without losing sight of this fact, the principal object of central-station bookkeeping is so to arrange these transactions under proper headings and groups as to enable us to ascertain: First, the cost of our product delivered to the consumer; second, the profit; third, the distribution of the costs into different accounts in such manner that we may determine where economies should be made in order to bring that cost down to a minimum, while giving the maximum efficiency of service to our consumer. This ought to be so arranged that it shall, while satisfying all the demands of the accountant, give the greatest possible information to the manager.

Lastly, the system should be flexible—that is, capable of expansion—so that the accounts may be further subdivided if desired by the larger companies. I have tried various methods of bookkeeping as set forth by different accountants, but when I was called on for a statement of one kind and another, week after week, as to where such an amount of money had gone, why it had gone there, why, with such and such receipts, the company did not show better net earnings, I found it impossible to give satisfactory answers or explanations with the system in vogue; it involved more labor than could be done in the time given.

The requirements of the Board of Railroad Commissioners for Street Railways in making up their annual reports seemed to me to be a good basis on which to work, and having with the aid of various experts—notably Frank H. Ford, of Ford, Bacon and Davis, New York city, and H. E. Babcock, auditor of Elmira Municipal Improvement Company—first secured the outline of a form for making up a monthly report for the railway company of which I had charge at that time, we proceeded, step by step, to work out a method of accounting that would seem to meet these and the other requirements. I now take pleasure in laying this system before you.

The Method: There are five general headings or groups of accounts, of which the first is Construction; second, Manufacturing; third, Distribution; fourth, General; fifth, Capital. The first includes all construction charges connected with the building and equipping of a plant. The second, third, fourth and fifth accounts are operating-expense accounts. These accounts in turn are subdivided as follows:

ELECTRIC LIGHT COMPANY

Construction Accounts:

1 Organization
2 Engineering and Superintendence
3 Franchises and Patents
4 Real Estate and Building
5 Steam Plant
6 Electrical Plant
7 Shop Tools and Machinery
8 Pole Lines and Circuits
9 Installations
10 Interest and Discount
11 Miscellaneous

Manufacturing Accounts:

(a) Operation:
12 Superintendence and Wages at Station
13 Fuel for Station
14 Water for Station
15 Lubricants and Waste for Station
16 Miscellaneous Manufacturing Supplies and Expenses
(b) Maintenance:
17 Repairs of Buildings
18 Repairs of Steam Plant
19 Repairs of Electrical Plant
20 Repairs of Shop Tools and Machinery
21 Renewals of Manufacturing Plant

Distribution Accounts:

(a) Operation:
22 Superintendence and Wages of Distribution
23 Incandescent Lamp Renewals
24 Arc Lamp Carbons
25 Miscellaneous Distribution, Supplies and Expenses
(b) Maintenance:
26 Repairs of Pole Lines and Circuits
27 Repairs of Installations
28 Renewals of Distribution System

General Accounts:

29 Salaries of General Officers and Clerks
30 Office Expenses and Supplies
31 Advertising
32 Insurance
33 Legal Expenses
34 Damages
35 Rent of Land and Buildings
36 Miscellaneous General Expenses

Capital Accounts:

37 Taxes
38 Interest on Investment
39 Interest on Current Liabilities
40 Investment Insurance
41 Reserve for Sinking Fund

GAS COMPANIES

Construction Accounts:

1 Organization
2 Engineering and Superintendence
3 Franchises and Patents
4 Real Estate, Buildings and Holders
5 Manufacturing Apparatus and Machinery
6 Tools and Testing Appliances
7 Mains and Services
8 Meters
9 Interest and Discount
10 Miscellaneous Construction

Manufacturing Accounts:

(a) Operation:
11 Wages at Works
12 Caking Coal
13 Enriching Coal
14 Crude Oil
15 Purifying Materials
16 Miscellaneous Manufacturing Supplies and Expenses
(b) Maintenance:
17 Repairs of Buildings and Holders
18 Repairs of Manufacturing Apparatus and Machinery
19 Repairs of Tools and Testing Appliances
20 Renewals of Manufacturing Plant

Distribution Accounts:

(a) Operation:
21 Wages of Distribution
22 Miscellaneous Distribution Expenses
(b) Maintenance:
23 Repairs of Mains and Services
24 Repairs of Meters
25 Repairs of Tools (Distribution System)
26 Renewals of Distribution System

General Accounts:

27 Salaries of Officers and Clerks
28 Office Expenses and Supplies
29 Advertising
30 Insurance

Manufacturing Accounts:

(a) Operation:
12 Superintendence and Wages at Station
13 Fuel for Station
14 Water for Station
15 Lubricants and Waste for Station
16 Miscellaneous Manufacturing Supplies and Expenses
(b) Maintenance:
17 Repairs of Buildings
18 Repairs of Steam Plant
19 Repairs of Electrical Plant
20 Repairs of Shop Tools and Machinery
21 Renewals of Manufacturing Plant

Distribution Accounts:

(a) Operation:
22 Superintendence and Wages of Distribution
23 Incandescent Lamp Renewals
24 Arc Lamp Carbons
25 Miscellaneous Distribution, Supplies and Expenses
(b) Maintenance:
26 Repairs of Pole Lines and Circuits
27 Repairs of Installations
28 Renewals of Distribution System

General Accounts:

29 Salaries of General Officers and Clerks
30 Office Expenses and Supplies
31 Advertising
32 Insurance
33 Legal Expenses
34 Damages
35 Rent of Land and Buildings
36 Miscellaneous General Expenses

Capital Accounts:

37 Taxes
38 Interest on Investment
39 Interest on Current Liabilities
40 Investment Insurance
41 Reserve for Sinking Fund

GAS COMPANIES

Construction Accounts:

1 Organization
2 Engineering and Superintendence
3 Franchises and Patents
4 Real Estate, Buildings and Holders
5 Manufacturing Apparatus and Machinery
6 Tools and Testing Appliances
7 Mains and Services
8 Meters
9 Interest and Discount
10 Miscellaneous Construction

Manufacturing Accounts:

(a) Operation:
11 Wages at Works
12 Caking Coal
13 Enriching Coal
14 Crude Oil
15 Purifying Materials
16 Miscellaneous Manufacturing Supplies and Expenses
(b) Maintenance:
17 Repairs of Buildings and Holders
18 Repairs of Manufacturing Apparatus and Machinery
19 Repairs of Tools and Testing Appliances
20 Renewals of Manufacturing Plant

Distribution Accounts:

(a) Operation:
21 Wages of Distribution
22 Miscellaneous Distribution Expenses
(b) Maintenance:
23 Repairs of Mains and Services
24 Repairs of Meters
25 Repairs of Tools (Distribution System)
26 Renewals of Distribution System

General Accounts:

27 Salaries of Officers and Clerks
28 Office Expenses and Supplies
29 Advertising
30 Insurance

class of manufacture, we find will occur every year. Let us take, then, the yearly proportion on the basis of lasting so many years, and place it each year under the head of investment insurance, and use that in our business for minor extensions or betterments and renewals sufficient to keep our plant intact and in as good operating condition as when first purchased; or, in other words, maintain our plant in such a manner that if a question of being compelled to sell it comes up, we can show that we have maintained it in such a way that the original investment is not impaired in the slightest.

Again, as regards a Reserve for Sinking Fund. Many have held to the idea that if they issue bonds for a term of fifty years, we will say, and pay the interest right along, that is all they can be asked to do; that when the time comes they can refund them, and therefore it is unnecessary to make any provision for a reserve sufficient to redeem the bonds at maturity. Others, again, say that by the time the bonds become due, our income will have increased so materially that we shall have no difficulty in taking care of them; they will be only a minor charge at that time; part of them can be redeemed and part renewed.

Neither of these views is the true economic way of looking at the subject. The only true way is to recognize the fact that the bonds must be redeemed at maturity, and to make provision for their redemption by setting aside each year such a reserve as will take care of the bonds at their maturity, charging this reserve as part of the operating expenses, or, in other words, as one of the factors of the cost of production. We may thus see that the cost of our product is legitimately represented by the four groups of accounts, Manufacturing, Distribution, General and Capital.

The method, then, is made up of these accounts and definitions. In addition to these, there is a monthly statement, a sample form for which is hereto appended, which includes not only the accounts in detail but the necessary operation data, the income account, the balance sheet and statement of cash receipts and disbursements, and of bills payable and construction charges.

The next question that comes up in connection with the method advocated is that of the books necessary to carry out the system perfectly. These books consist of:

Distribution Journal
Operating Expense Ledger
General Cash Book
Storekeeper's Ledger
Consumers' Ledger
General Ledger
Journal

To these may be added for larger companies,
Cashier's Cash Blotter
Meter Record Book
Distribution of Cash
Check Record
Delinquent Bills

The Distribution Journal is the book in which all bills received, after being numbered and approved, are entered, and its pages, beginning at the extreme left, are divided into spaces headed by the numbered accounts previously mentioned. The last column on the left-hand page is headed "In Acct. With" under which is "Sundries Debtor To," and contains the names of parties credited with bills, being preceded by two columns for date and number of bills, respectively, while the first two columns on right-hand page are devoted to ledger folio and amount of credit, respectively. The charges to the numbered accounts, which occupy the remaining spaces on both pages, are made under the proper heading on the same line with the credit to the individual. The credits are posted from the distribution journal to the account of the party credited on the general ledger, while the debits are posted at the end of the month to the operating-expense ledger, which is simply a ledger containing only the numbered accounts with definitions of each.

The General Cash Book consists of two pages, debit and credit. The first column of the debit page is for the date; the next, headed "Receipts," is for the name of the individual remitting, followed by a column for ledger folio. The balance of the page is divided into columns headed, "Sundries," "Consumers' Ledger," "Deposits," "Interest," "Bills Receivable," and any other necessary accounts which may vary in different companies. The first column on the credit side is for date, the next for voucher number, and these are followed by a column headed "Disbursements," under which come names of parties to whom remittances are made. Next to this comes a column for invoice numbers, under which should be placed number of bills paid and a column for ledger folio. The remaining space is divided similarly to the debit page, with columns headed "Sundries," "Discount," "Rebates," "Deposits Refunded," etc., according to individual needs.

The Storekeeper's Ledger consists of columns subdivided into two spaces headed "Receipts" and "Deliveries;" these in turn are subdivided into two spaces each, marked in each case, "Date" and

"Quantity." There may be as many of these columns as the size of the book will allow.

The Consumers' Ledger has spaces for the first six months on the extreme left side of the book and for the remaining six months on the extreme right. Between, are two columns, the first headed "——— Street," which is subdivided into three columns for "Name," "Street No." and "Deposit," respectively. The second column is headed "Memoranda," and is subdivided into two columns, "Meters" and "Remarks." "Meters" is further divided into columns for "Company's No.," "Size" and "Date," and column for "Date" is again divided into two, headed "Set" and "Removed." The spaces for months are divided into three columns, headed "Index," "Current" and "Amount and When Paid." "Current" column is subdivided into three columns, headed "Light," "Power" and "Special."

The General Ledger and Journal are ordinary books of that kind, and need no special explanation. The Cashier's Cash Blotter is a record of receipts and disbursements of cash for the month. The first column on the page is for the date, the rest of the page being divided into three equal spaces, headed "Receipts," "Disbursements" and "Deposited In." Under the heading of "Receipts" come receipts from accounts determined by the company, and this also applies to "Disbursements."

The Meter Record has space at the top of the page for name and address of consumer, under which are lines left blank for meter number, date of installation and size. Book for Distribution of Cash has each page horizontally divided into two equal parts, making four on the two pages. Of these, the first one is headed "Receipts," and under it come all the accounts for which cash is received during the month. The other three spaces are for disbursements, and are subdivided into the numbered accounts and any additional accounts for which cash is disbursed, such as Discount, Deposits Refunded, etc.

The Check Record is designed to keep track of all checks given, to whom given and for what purpose. The columns into which it is divided are headed "Date," "Number of Check," "In Favor Of," "Amount," "No. of Voucher," "Date," "Deposit," "Balance" and "Remarks." Book for Delinquent Bills has space at top for name of month, under which it is divided into columns for ledger, ledger folio, name, location, kind of light used, whether regular or special, amount, when paid and remarks.

Here, then, is a method of accounting that has been found to work satisfactorily in practice, that is comparatively simple, and that may be elaborated so as to show many minor divisions where such may be deemed necessary in larger companies. I do not claim for it any great originality, or even that it is very materially different from the methods that many of the members of the association are now using, except in the matter of capital accounts. I believe it does possess sufficient merit to warrant its adoption by all the members of the association, and it is presented for your consideration in order that a uniform system of accounting may be used by all the members.

The number of agitators that are crying municipal ownership of public utilities is constantly and rapidly increasing; they are attacking us in all parts of the country even now, and the attack will be stronger and stronger as time goes on. Our plan of defense must lie in the correct determination of costs, and in showing that while we are exercising the functions of a monopoly, we are only attempting to realize therefrom a legitimate profit for the capital we have invested in the enterprise. To do this we must have uniformity of accounting, in order that we may present a solid front and be able to disarm the agitators by showing to the people at large that we are following fair business methods and only obtaining a fair return on our investments. If we are able, then, to convince the people of this, they in turn will support us in our rights, will see that we are given the privilege of exercising the functions of a monopoly under proper laws, and will realize the necessity for granting us exclusive franchises, in order that the best economy of operation may be effected, and the people furnished with light and power at a minimum cost.

GAS DEPARTMENT

CLASSIFICATION OF CONSTRUCTION ACCOUNTS

1 *Organization:*

This account includes all expenses incurred in effecting organization, including legal expenses.

2 *Engineering and Superintendence:*

This account includes wages and expenses of engineers and draughtsmen, inspectors, superintendents, etc., on preliminary and construction work.

3 *Franchises and Patents:*

This account includes the cost of all franchises, privileges and patent rights, except when these are in the nature of an annual tax or royalty, in which case they are charged against income.

4 *Real Estate, Buildings and Holders:*

This account is charged with the cost of all real estate, and buildings and improvements in connection with same; also holders owned by the company, including excavations, foundations, drainage, water, gas and sewer pipes and stationary fixtures belonging thereto, heating and lighting apparatus and fixtures; other stationary fixtures and other office furniture and fixtures, sidewalks, street paving on streets in front of or adjacent to buildings, fences, sheds, outhouses, etc.; and the cost of coal tracks and scales in the yard.

5 *Manufacturing Apparatus and Machinery:*

This account is charged with the cost of manufacturing apparatus and machinery complete, exclusive of buildings, and includes engines and engine parts, boilers, furnaces, stacks, pumps, feed and water heaters, piping and steam fitting, including valves, water and sewer connections and water meters, benches of retorts, friction and tower scrubbers, tar extractors, exhausters, purifying boxes, ammonia and tar tanks, station meter, controller and appliances, and fixtures pertaining to each of above up to inlet of holders.

6 *Tools and Testing Appliances:*

This account includes all tools used about the works, including tools used in the repair shops and for outside work, all testing appliances and instruments, thermometers, gauges other than steam gauges attached to the boilers.

7 *Mains and Services:*

This account is charged with the cost of all mains laid, starting at outlet of holders, cost of all services that are put in at the expense of the company; curb wells, curb cocks, drip wells, valves and gates of whatever kind used in connection with mains or services, put in at the expense of the company, are included in this account.

8 *Meters:*

This account is charged with the cost of all gas meters, meter cocks and meter connections, including cost of transportation, storage and handling until delivered in the stock-room.

9 *Interest and Discount:*

All interest and discount paid and received in connection with funds for construction should be charged or credited under this account.

10 *Miscellaneous:*

This account includes cost of any apparatus, machinery or appliances not properly chargeable to any of the foregoing accounts; electrical apparatus, pole lines and their appurtenances; also miscellaneous expenses and office expenses not otherwise provided for, incurred during and in connection with construction work.

CLASSIFICATION OF OPERATING EXPENSE ACCOUNTS

MANUFACTURING

(a) OPERATION

11 *Superintendence and Wages at Works:*

This account includes one-half the salary of the superintendent, and the wages of all men employed at the works in connection with the manufacture of gas.

12 *Caking Coal for Works:*

This account includes the cost of caking coal delivered in the coal sheds at works, and all transportation charges and handling charges up to that point.

13 *Enriching Coal for Works:*

This account includes the cost of enriching coal delivered in the coal sheds at the works and all transportation and handling charges incurred up to that point.

14 *Crude Oil for Works:*

This account includes the cost of crude oil delivered in the storage tanks at the works, and includes transportation and handling charges up to that point.

15 *Purifying Materials for Works:*

This account includes cost of iron oxide, lime, or any other form of material used in the purification of gas, and includes cost of transportation and handling up to the time of delivery at the works.

16 *Miscellaneous Manufacturing Supplies and Expenses:*

This account includes cost of miscellaneous supplies and expenses not otherwise provided for that may be incurred in connection with the manufacture of gas.

(b) MAINTENANCE

17 *Repairs of Buildings and Holders:*

This account includes cost of labor, materials, supplies and expenses of repairs to buildings, including buildings and holders at works, stables, office buildings, sheds, coal bins and improvements in connection with same, including drainage, water, gas and sewer pipes and stationary fixtures belonging thereto; heating and lighting fixtures, other stationary fixtures and office fixtures and furniture, sidewalks, street paving on streets in front of or adjacent to buildings, fences, sheds, outhouses, etc., and repairs to scales in the yard. This account does not include repairs of buildings not used in connection with the operation of the plant. If such buildings be leased to other parties the cost of repairs is deducted from the account which includes the rent received.

18 *Repairs of Apparatus and Machinery:*

This account is chargeable with cost of all repairs to apparatus and machinery used in connection with the manufacture of gas, stopping at inlet to holders.

19 *Repairs of Tools and Testing Appliances:*

This account is chargeable with cost of repairs of all tools and testing appliances used in connection with the manufacture of gas.

20 *Renewals of Manufacturing Plant:*

This account is chargeable with the cost of renewals of any part of the manufacturing plant, including buildings, holders, apparatus and machinery, tools, testing appliances, etc., and, as distinguished from repairs, means where a new thing is purchased outright to replace anything worn out and incapable of being repaired. The replacing of an article of larger first cost is charged to this account to the extent of that part of the first cost of the new article that is equal to the book value of the article unfit for use, and the balance charged to construction account. This account is credited by the sale of old material and by the principal of insurance to be recovered through fire losses.

CLASSIFICATION OF DISTRIBUTION ACCOUNTS

(a) OPERATION

21 *Superintendence and Wages of Distribution:*

This account includes one-half of the salary of the superintendent, and the wages of all those employed in installing, reading and removing meters and gas stoves, except when employed on repairs; also all those employed in connection with laying services.

22 *Miscellaneous Distribution Expenses:*

This account is chargeable with any miscellaneous distribution expenses not otherwise provided for.

(b) MAINTENANCE

23 *Repairs of Mains and Services:*

This account is chargeable with cost of labor, materials, supplies and expenses for the repairs of mains, curb wells, curb cocks, gates, valves, drip wells and services, and gas stoves when owned by the company; and also includes stabling, horseshoeing, etc., not properly chargeable to construction, together with the repairs to wagons and harnesses.

24 *Repairs of Meters:*

This account is charged with cost of repairs of meters used for metering gas.

25 *Repairs of Tools:*

This account is chargeable with cost of repairs of tools used in digging trenches and general installation work.

26 *Renewals of Distribution System:*

This account is chargeable with cost of renewals of anything pertaining to distribution system, and includes renewals of meters, services and mains, tools used for digging trenches and general installation where these are worn out to such an extent that they are beyond repair. The replacing by an article of larger first cost is charged to this account to the extent of that part of the first cost of the new article that is equal to the book value of the article unfit for use, and the balance charged to construction account. This account is credited with the sale of old material and with the principal of insurance to be recovered through fire losses.

CLASSIFICATION OF GENERAL ACCOUNTS

27 *Salaries of General Officers and Clerks:*

This account includes salary of president, vice-president, secretary, treasurer, general manager, auditor, cashier, and their assistants, draftsmen, bookkeepers, collectors, solicitors for new business, stenographers, porters, cleaners, etc.; together with all clerks. in general offices and clerks for heads of departments.

28 *Office Expense and Supplies:*

This account includes cost of heating and lighting offices, stationery and printing of blanks, and miscellaneous office supplies and expenses, including account books, postage, telegrams, telephone service, newspapers and periodicals.

29 *Advertising:*

This account includes cost of newspaper and miscellaneous advertising, together with salaries of advertising agents.

30 *Insurance:*

This account includes cost of fire, casualty, employers' liability and fidelity and other insurance.

31 *Legal Expenses:*

This account includes fees and retainers paid attorneys when not regularly employed by the company; also fees and other expenses of arbitrators for settlement of disputed questions, cost of suits, special fees, notarial fees, expenses connected with taking depositions, and all legal and court expenses of every kind not otherwise provided for.

32 *Rent of Land and Buildings:*

This account includes all rent paid for lease of land and buildings used in the operation of the company.

33 *Miscellaneous General Expenses:*

This account includes cost of entertainments, traveling expenses of general office employees, dues to societies, subscriptions, donations and all contingent expenses connected with the general management not otherwise provided for.

ELECTRIC DEPARTMENT

CLASSIFICATION OF CONSTRUCTION ACCOUNTS

1 *Organization :*

This account includes all expenses incurred in effecting organization, including legal expenses.

2 *Engineering and Superintendence :*

This account includes wages and expenses of engineers, draftsmen, inspectors, superintendents, etc., on preliminary and construction work.

3 *Franchises and Patents :*

This account includes the cost of all franchises, privileges and patent rights, except when these are in the nature of an annual tax or royalty, in which case they are charged against income.

4 *Real Estate and Buildings :*

This account includes the cost of all real estate and buildings and improvements owned by the company, including excavations, drainage, water for house purposes, gas and sewer pipes and stationary fixtures belonging thereto; heating and lighting apparatus and fixtures, elevators and all other stationary fixtures, and office furniture and fixtures; sidewalks, street paving on streets in front of or adjacent to buildings, fences, sheds, outhouses, etc.

5 *Steam Plant :*

This account includes cost of steam plant complete, exclusive of buildings and electrical plant, and inclusive of stacks, stack foundations, coal and ash handling apparatus and hoists, boilers, boiler foundations, pumps, condensers, feed-water heaters, steam-piping system with accessories, water-piping system used in connection with steam apparatus, shafting, clutches, belting and accessories, and all other devices and appliances appertaining to the above items, including traveling cranes, etc.

6 *Electrical Plant:*

This account includes cost of electrical plant complete, exclusive of buildings and steam plant, and including dynamos, dynamo foundations, electrical conductors and switchboards, cables, feeder terminals, storage batteries, station transformers, boosters, rheostats, circuit breakers, motors, switches and all other electrical station equipment.

7 *Shop Tools and Machinery:*

This account includes the cost of shop tools and machinery for repair shops for the repair of general machinery, arc lamp meters, transformers, etc., including foundations and installation of such machinery. This account also includes cost of horses, harness and vehicles for construction or repairs.

8 *Pole Lines and Circuits:*

This account includes cost of the distribution system complete, exclusive of installations, and including cost of labor, materials, supplies, tools, and expenses of poles, pole fixtures, pole setting and painting, wire insulators, and small apparatus forming part of the circuits, such as junction boxes, pole cutouts, lightning arresters, etc., and connections to, but not including, arc lamps, and hauling, storing and distributing construction material. Where underground construction is used, the cost of underground conduits and wiring system is included in this account.

9 *Installations:*

This account includes the cost of interior wiring installations if owned by the company, arc lamps, transformers, motors, fans and service apparatus, such as meters, cutouts, switches, etc., used by the consumer and owned by the company, including cost of installation.

10 *Interest and Discount:*

This account includes charges or credits for all interest and discount paid or received in connection with funds for construction, and also all taxes or other fixed charges paid during construction.

11 *Miscellaneous:*

This account includes miscellaneous expenses, office expenses, wages of clerks, and all other expenses in connection with construction that would not be allowed in any of the accounts enumerated above.

CLASSIFICATION OF OPERATING EXPENSE ACCOUNTS—"A" MANUFACTURING

(a) OPERATION

12 *Superintendence and Wages at Station:*

This account includes one-half the salary of the superintendent, and wages of engineers, oilers, firemen, dynamo tenders, machinists, cleaners, helpers and all other employees at the station, except when employed on "repairs," "renewals," etc.

13 *Fuel for Station:*

This account includes the cost of coal, fuel, oil or other fuel delivered in fireroom, including all charges for hoisting, unloading, trimming, carting, coal passers, etc.

14 *Water for Station:*

This account includes cost of all water used at station.

15 *Lubricants and Waste for Station:*

This account includes cost of all oils, grease, rags and waste used in the lubrication and cleaning of machinery at station, including transportation charges.

16 *Miscellaneous Manufacturing Supplies and Expenses:*

This account includes the cost of packing, gaskets, brushes, fuses, lamps, carbons, and all other miscellaneous supplies used in the operation of the station, except such as are used for "repairs." This account also includes cost of storing and handling these supplies. This account also includes all miscellaneous expenses of manufacturing not included in the operating accounts.

(b) MAINTENANCE

17 *Repairs of Buildings:*

This account includes cost of labor, all materials and supplies, tools and expenses for the repairs of buildings, including stations, repair shops, stables, office buildings, sheds and coal bins, with all improvements in connection with same, such as drainage, water, gas and sewer pipes, heating and lighting apparatus and fixtures, sidewalks and street-paving obligations due to the ownership of such property. This account does not include the repairs of buildings not used in connection with the operation of the lighting company. If such buildings be leased to other parties, the cost of repairs is deducted from the account which includes the rent received.

18 *Repairs of Steam Plant:*

This account includes cost of labor, materials, supplies, tools and expenses for the repair of steam plant, including stacks, stack foundations, coal and ash-handling apparatus, traveling cranes and hoists, boilers, boiler foundations and settings, boiler breechings and flues, engines and foundations, pumps, condensers, feed-water heaters, economizers, steam-piping system with accessories, water-piping system used in connection with steam apparatus, shafting, clutches, belting and accessories, and all other devices and appliances appertaining to above items.

19 *Repairs of Electrical Plant:*

This account includes cost of labor, material, supplies, tools, expenses of repair for electrical plant, including dynamos, dynamo foundations, electrical conductors, switchboard, cables, feeder terminals, storage batteries, station transformers, boosters, rheostats, circuit breakers, meters switches, and all other electrical station equipment.

20 *Repairs of Shop Tools and Machinery:*

This account includes cost of labor, material, supplies and expenses for repair of shop tools and machinery of the repair shop.

21 *Renewals of Manufacturing Plant:*

This account includes cost of replacing and renewing when unfit for economical service, due to wear, or injury by fire or accident, of all of the items of steam plant. This account includes cost of labor and materials necessary for replacing each item with another of the same value. Replacing by an article of larger first cost is charged to this account to the extent of that part of the first cost of the new article that is equal to the cost of the article unfit for use, and the balance charged to Construction Account. This account is credited by the sale of old material and by the principal of insurance recovered by fire losses. Charges are made as "Renewals" if for complete articles replaced, such as an engine, a dynamo, etc. If a charge is for a part of a whole article, such as an armature of a dynamo or tubes in a boiler, etc., it should be classified as "Repairs."

"B" DISTRIBUTION

(a) OPERATION

22 *Superintendence and Wages of Distribution:*

This account includes one-half the salary of the superintendent, and the wages of the trimmers, inspectors, linemen, helpers, meter inspectors, including reading of meters, store-keepers and all other employees connected with the distribution system, except when occupied upon repairs.

23 *Incandescent Lamp Renewals:*

This account includes cost of incandescent lamps used in replacing those burned out or destroyed in service, together with the cost of handling or storage. All sums received from customers for lamps to replace breakage are credited to this account.

24 *Arc Lamp Carbons:*

This account includes the cost of all carbons delivered in the store-room.

25 *Miscellaneous Distribution Supplies and Expenses:*

This account includes cost of arc lamps, globes and all other miscellaneous supplies and expenses of the distribution system not included in other distribution accounts of operation.

(b) MAINTENANCE

26 *Repairs of Pole Lines and Circuits:*

This account includes cost of labor, material, supplies, tools and expenses for the repair of pole lines and circuits, including poles, pole fixtures, pole setting and painting, wire, insulators, and small apparatus forming part of the circuits, such as junction boxes, pole cutouts, lightning arresters, etc. Where underground construction is used, the cost of repairs of underground and wiring system is included. This account also includes all charges for stabling not properly chargeable to construction account, together with repairs for harness and wagons, horseshoeing, etc.

27 *Repairs of Installation:*

This account includes cost of labor, material, supplies, tools and expenses for the repair of interior wiring installations, if owned by the company; arc lamps, transformers, motors, fans and service apparatus, such as meters, cutouts, switches, etc., used by the consumers and owned by the company, when not chargeable to the consumer. This account also includes the changing of the location of the arc lamps, incandescent lamps or motors, replacing cutouts, fuses, etc.

28 *Renewals of the Distribution System:*

This account includes cost of replacing and renewing when unfit for economical service, due to wear or injury by fire or accident, of all of the items of the pole lines and circuits and installations. This account includes the cost of labor and materials necessary for the replacing of each item by another of the same value. The replacing by an article of larger first cost is charged to this account to the extent of that part of the first cost of the new article that is equal to the book value of the article unfit for use, and the balance charged to construction account. This account is credited with the sale of old materials, and by the principal of insurance recovered through fire losses.

29 *Salaries of General Officers and Clerks:*

This account includes salaries of president, vice-president, secretary, treasurer, auditor, general manager, chief engineer, purchasing agent, assistant general managers, assistant engineers, draftsmen, contracting agents, cashier, assistant cashiers, bookkeepers, collectors, solicitors for new business, stenographers, porters, cleaners, etc., together with all clerks in general office and clerks for heads of departments.

30 *Office Expenses and Supplies:*

This account includes heating and lighting of offices, stationery and printing of blanks, and miscellaneous office supplies and expenses, including account books, postage, telegrams, telephone service, newspapers and periodicals.

31 *Advertising:*

This account includes cost of newspaper and miscellaneous advertising, together with the salaries of advertising agents.

32 *Insurance:*

This account includes cost of fire, casualty, employers' liability, profits and other insurance.

33 *Legal Expenses:*

This account includes fees and retainers paid attorneys when not regularly employed by the company; also fees and other expenses of arbitrators for settlement of disputed questions, cost of suits, special fees, notarial fees, expenses connected with taking depositions, and all legal and court expenses of every kind not otherwise provided for under the account "Damages."

34 *Damages:*

This account includes all charges on account of persons killed or injured, such as gratuities and pensions paid to injured or disabled persons, their creditors, heirs, relatives and attorneys; salaries and expenses of doctors, coroners and undertakers, witnesses and others (except lawyers' fees and court expenses); nursing, hospital attendance, medical and surgical supplies, and wages and expenses of those occupied in connection with the adjustment of claims.

35 *Rent of Land and Buildings:*

This account includes all rents paid for lease of land and buildings used in the operation of the company.

36 *Miscellaneous and General Expenses:*

This account includes cost of entertainments, traveling expenses of general office employees, dues of National Electric Light Association or other societies, subscriptions, donations, and all contingent expenses connected with the general management not otherwise provided for.

"D" CAPITAL

37 *Taxes:*

This account includes all moneys paid as state, county or city taxes in whatever form they may be levied.

38 *Interest on Investment:*

This account includes interest on total money invested in the business of the company, and in case bonds are issued interest should be reckoned at the rate at which bonds are placed upon the market. The funded debt in the shape of bonds should, in general, cover the amount of money invested in the business as capital. In case of loans being made, other than in the shape of bonds, they should, if deemed to be issued for more than a temporary period, be reckoned as part of the investment, and interest charged to this account.

39 *Interest on Current Liabilities:*

This account includes interest on temporary loans and interest on bills payable, and should be credited with interest received on bills receivable or moneys loaned temporarily by the company.

40 *Investment Insurance:*

This account includes the premium on the entire investment, usually reckoned at from five per cent to seven and one-half per cent, according to local conditions, which is to be set apart as a fund to provide for such replacements and extraordinary repairs as will maintain the plant in such condition that its present worth will always be equal to the original amount invested. To this end minor extensions or betterments for which it is deemed unnecessary to issue bonds or stock should be charged to the extent of the amount realized from the premium.

41 *Reserve for Sinking Fund:*

This amount includes the necessary charges to provide a fund for the redemption at maturity of bonds issued.

OPERATION DATA

Manufacture	K.-W. Hours at Switchboard				
	190	190	Increase or Decrease.		
Output for Month					
Arc System					
Municipal Service					
Private Consumers					
Incandescent System					
Power System					
Railway Service					
Private Consumers					
Total					

Distribution	Number of Consumers			Number of Lamps Con.				
Connec'd Load at end of Mo	190	190	Increase or Decrease	190	190	Increase or Decrease		
Arc System								
Municipal Service								
Private Consumers								
Incandescent System								
Power System				H. P. Connected				
Railway Service								
Private Consumers								
Totals								

	K.-W. Hours at Consumers' Meters				
Input for Month	190	190	Totals		
Arc System					
Municipal Service					
Private Consumers					
Incandescent System					
Power System					
Railway Service					
Private Consumers					
Totals					

	K.-W. Hours			Per Cent of Output				
Loss in Distribution	190	190	Increase or Decrease	190	190	Increase or Decrease		
Output less Input								
Arc System								
Incandescent System								
Power System								
Totals								

	190	190	Increase or Decrease		
Carbons used					
Arc Lamp Globes replaced					
Incan. Lamp Renewals					

	Fuel	
	Quality	
	Amount of Coal per K.-W. Hour	
	Watt Hours per pound Coal	
	Ratio Average Load to Connected Load.	
	" Max. " " " "	

RED INK FIGURES DENOTE DECREASE

INCOME

Gross Earnings from Operation	190	Per Cent of Gross Earnings	Per K.-W. Hour Generated	190	Per Cent of Gross Earnings
ARC SYSTEM					
Municipal Service					
Private Consumers					
Total					
INCANDESCENT SYSTEM					
Power System					
Railway Service					
Private Consumers					
Total					
Total Gross Erngs. from Oper.					
Operating Expenses					
A Manufacture					
B Distribution					
C General					
D Capital					
Total Operating Expenses					
Net Income from Operation					
Income from other Sources					
Profit from Wiring Department					
Rent of Land and Buildings					
Interest					
Total Inc. from Other Sources					
Gross Income from all Sources					
Deductions from Gross Income					
Dividends					
Total Deduc'ns from Gross Inc.					
Surplus					
Deficit					

ACCOUNT

Per K. W. Hour Generated	Increase or Decrease 190	Per Cent of Increase or Decrease	Total from 190	Per Cent of Gross Earnings	Per K.-W. Hour Generated	Total from 190	Per Cent of Gross Earnings	Per K.-W. Hour Generated	Increase or Decrease 190	Per Cent of Increase or Decrease

RED INK FIGURES DENOTE DECREASE

OPERATING

A—Manufacture	190						Per K.-W. Hour Generated	190		
(A) Operation										
12 Superintendence and Wages at Station										
13 Fuel for Station										
14 Water for Station										
15 Lubricants and Waste for Station										
16 Miscellaneous Mfg. Supplies and Expenses										
Total										
(B) Maintenance										
17 Repairs of Buildings										
18 " " Steam Plant										
19 " " Electrical Plant										
20 " " Shop Tools and Machinery										
21 Renewal of Manufacturing Plant										
Total										
B—Distribution										
(A) Operation										
22 Superintendence and Wages of Dis.										
23 Incandescent Lamp Renewals										
24 Arc Lamp Carbons										
25 Miscellaneous Distribution Supplies and Expenses										
Total										
(B) Maintenance										
26 Repairs of Pole Lines and Circuits										
27 Repairs of Installations										
28 Renewals of Distribution System										
Total										
C—General										
29 Salaries of General Officers and Clerks										
30 Office Expenses and Supplies										
31 Advertising										
32 Insurance										
33 Legal Expenses										
34 Injuries and Damages										
35 Rent of Land and Buildings										
36 Miscellaneous General Expenses										
Total										
D—Capital										
37 Taxes										
38 Interest on Investment										
39 Interest on Current Liabilities										
40 Investment Insurance										
41 Reserve for Sinking Fund										
Total										
Total Operating Expenses										

EXPENSES

Per K.-W. Hour Generated	Increase or Decrease 190	Per Cent of Increase or Decrease	Total from 190	Per K.-W. Hour Generated	Total from 190	Per K.-W. Hour Generated	Increase or Decrease 190	Per Cent of Increase or Decrease

BALANCE SHEET

Assets At July 1, 190									
Construction and Equipment									
1 Organization For Fiscal Yr. 190									
2 Eng'ng and Superintendence. " "									
3 Franchises and Patents " "									
4 Real Estate and Buildings " "									
5 Steam Plant " "									
6 Electrical Plant " "									
7 Shop Tools and Machinery " "									
8 Pole Lines and Circuits " "									
9 Installations " "									
10 Interest and Discount " "									
11 Miscellaneous " "									
Stocks and Bonds									
Current Assets									
Cash									
Bills Receivable									
Accounts Receivable									
Supplies on Hand									
Prepaid Accounts—Insurance									
Taxes									
Total Resources									
Operating Expenses from to									
Deductions from Income from to									
Total Expenses and Deductions									
Liabilities									
Capital Stock									
Mortgage Bonds									
Bills Payable—Bank Loans									
Commercial Paper									
Accounts Payable									
Salaries and Pay Rolls Payable									
Accrued Accounts—Interest									
Taxes									
Total Liabilities									
Profit and Loss									
Earnings from Operation from to									
Income from Other Sources from to									
Gross Earnings									

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS

RECEIPTS				DISBURSEMENTS			
Balance on Hand..........190...				Bills Payable			
Receipts from Earnings				Accounts Payable			
" " Profit from Wiring Department				Interest on Bonds			
				" " Loans			
" " Rentals				Pay Rolls and Salaries			
" " Interest				Dividends			
" " Bills Payable							
Bills Receivable							
Accounts Receivable							
Sale of Bonds							
Total Receipts				Total Disbursements			
				Balance on Hand			

BILLS PAYABLE

Outstanding First of Month				
Issued During Month				
Retired During Month				
Balance Outstanding				

CONSTRUCTION CHARGES

1 Organization			
2 Engineering and Superintendence			
3 Franchises and Patents			
4 Real Estate and Buildings			
5 Steam Plant			
6 Electrical Plant			
7 Shop Tools and Machinery			
8 Pole Lines and Circuits			
9 Installations			
10 Interest and Discount			
11 Miscellaneous			
Total Charges for Construction			

ELECTRIC DEPARTMENT

FOR MONTH OF

....190

STATEMENT OF
INCOME ACCOUNT

ANALYSIS OF
OPERATING EXPENSES
CONSTRUCTION CHARGES
CASH RECEIPTS AND
DISBURSEMENTS

BALANCE SHEET, ETC.
WITH
COMPARISONS

....
Head Bookkeeper

Approved

....
General Manager

OPERATION DATA

	190	190		
Gas Manufactured—Cubic Feet				
Gas sold to Consumers—Illuminating—Cubic Feet				
Gas sold to Consumers—Fuel—Cubic Feet				
Gas sold for Street Lamps—Cubic Feet				
Gas used in Works, Offices and Stores—Cubic Feet				
Total Gas sold and used by the Company—Cubic Feet				
Leakage—Cubic Feet				
Coal Carbonized—Pounds				
Gas Oil used—Gallons				
Coke Manufactured—Bushels				
Coke Consumed—Bushels				
Tar Manufactured—Gallons				
Tar Sold—Gallons				
Tar on hand at end of month—Gallons				
Ammonia Manufactured—Gallons				
Ammonia Sold—Gallons				
Ammonia on Hand at end of month—Gallons				
Cost of Gas in holder per 1,000 Cubic Feet				

	Number of Consumers		Increase or Decrease
	190	190	
Illuminating			
Fuel			

RED INK FIGURES DENOTE DECREASE

INCOME

Gross Earnings from Operation	190	Per 1,000 Cubic Feet	Per 5-ft. Burner	Per Cent of Receipts	190	Per 1,000 Cubic Feet	Per 5-ft. Burner
Gas Sales							
Illuminating Gas							
Fuel Gas							
Sales of Coke							
Sales of Tar							
Sales of Ammonia							
Total Gross Earnings from Operation							
Operating Expenses							
A Manufacturing							
B Distribution							
C General							
D Capital							
Total Operating Ex.							
Net Income from Operation							
Income from other Sources							
Profit from Gas Stove Department							
Rent of Land and Bldgs							
Interest and Dividends							
Total Income from other Sources							
Gross Income from all Sources							
Deductions from Gross Income							
Dividends							
Total Deductions from Gross Income							
Surplus							
Deficit							

ACCOUNT

Per Cent of Receipts	Increase or Decrease 190	Per Cent of Increase or Decrease	Total from 190	Per 1,000 Cubic Feet	Per 5-ft. Burner	Per Cent of Receipts	Total from 190	Per 1,000 Cubic Feet	Per 5-ft. Burner	Per Cent of Receipts	Increase or Decrease 190	Per Cent of Increase or Decrease

RED INK FIGURES DENOTE DECREASE

OPERATING

A—Manufacturing	190						Per 1,000 Cubic Feet Mfd.	Per 5-ft. Burner	190			Per 1,000 Cubic Feet Mfd.
(a) Operation												
11 Superintend. and Wages at Works												
12 Caking Coal for Works												
13 Enriching Coal for Works												
14 Crude Oil for Works												
15 Purifying Materials for Works												
16 Miscellaneous Manufacturing Supplies and Expenses												
Total												
(b) Maintenance												
17 Repairs of Buildings and Holders												
18 Repairs of Manufacturing Apparatus and Machinery												
19 Repairs of Tools and Testing Appliances												
20 Renewals of Manufacturing Plant												
Total												
B—Distribution												
(a) Operation												
21 Superintendence and Wages of Distribution												
22 Miscellaneous Distribution Ex.												
Total												
(b) Maintenance												
23 Repairs of Mains and Services												
24 Repairs of Meters												
25 Repairs of Tools												
26 Renewals of Distribution System												
Total												
C—General												
27 Salaries of Gen. Officers and Clerks												
28 Office Expenses and Supplies												
29 Advertising												
30 Insurance												
31 Legal Expenses												
32 Rent of Land and Buildings												
33 Miscellaneous General Expenses												
Total												
D—Capital												
34 Taxes												
35 Interest on Investment												
36 Interest on Current Liabilities												
37 Investment—Insurance												
38 Reserve for Sinking Fund												
Total												
Total Operating Expenses												

EXPENSES

Per 5-ft. Burner	Increase or Decrease 190			Per Cent of Increase or Decrease	Total from 190			Per 1,000 Cubic Feet Mfd.	Per 5-ft. Burner	Total from 190			Per 1,000 Cubic Feet Mfd.	Per 5-ft. Burner	Increase or Decrease 190			Per Cent of Increase or Decrease

BALANCE SHEET

Assets..........At July 1, 190									
Construction Accounts									
1 Organization..........For Fiscal Yr. 190.									
2 Eng'ng and Superintendence. " "									
3 Franchises and Patents....... " "									
4 Real Estate, Bldgs. and Hldrs. " "									
5 Mfg. Apparatus and Machin.. " "									
6 Tools and Testing Appliances " "									
7 Mains and Services.......... " "									
8 Meters.................... " "									
9 Interest and Discount........ " "									
10 Miscellaneous................ " "									
Stocks and Bonds									
Current Assets									
Cash									
Bills Receivable									
Accounts Receivable									
Supplies on Hand									
Prepaid Accounts—Insurance									
Taxes									
Total Resources									
Operating Expenses from............to									
Deductions from Income from........to									
Total Expenses and Deductions									
Liabilities									
Capital Stock									
Mortgage Bonds									
Bills Payable—Bank Loans									
Commercial Paper									
Accounts Payable									
Salaries and Pay Rolls Payable									
Accrued Accounts—Interest									
Taxes									
Total Liabilities									
Profit and Loss									
Earnings from Operation from..........to									
Income from Other Sources from........to									
Gross Earnings									

and municipal ownership have been combined. I regret that, as I think they should have been separated. I do not believe one has anything to do with the other. I think the great trouble with the majority of electric-light companies in this country at the present time is the fact that they have not the remotest idea as to what their cost is, or what goes to make up cost. Mr. Doherty, suppose we have a small company with a thousand horse power of electrical apparatus, and for one reason or another it is desirable that the apparatus should be thrown aside and new apparatus purchased; should not either the new apparatus or the old apparatus be charged against operating expenses?

MR. DOHERTY: I think you misunderstood me; and if it will not interfere with what you have to say, I will make my position clear. The Street Railway Accountants' Association recommends that from the gross income shall be deducted taxes, interest on current liabilities, and insurance in some cases, and items of that sort. The point I make is this, that income is income, and you can hardly report an income after deducting certain payments from it. That is the only point. In answer to your question, I think the charge should go to operating expenses when you scrap an old machine, or it must be taken from the profit and loss account.

MR. INSULL: It should not be taken from the profit and loss account. It is not a deduction from income at all; you are deducting it from something you haven't got. For instance, if you buy coal, you consume it, and that goes against your operating expenses. If you buy dynamos, and for one reason or another you throw them one side, you consume the dynamos, and therefore they should go to operating expenses in some form or another.

MR. DOHERTY: I might operate a plant for five years. I can not easily predict what the depreciation will be on certain portions of that plant. I might cite, for example, the case of our constant-current arc machines. A few years ago they represented an operating worth closely approximating that of the day they were purchased. To-day, many of us believe that a newer system is far superior to that, so that we may possibly junk these constant-current arc machines. Now, to deduct this from operating expenses would perhaps leave us one year without any earnings at all, while the consumption of the dynamo has gone on for ten years back, and we have not deducted any operating expenses for these ten years; but the amount we did not deduct has been carried to the profit and loss or surplus account. The only thing I can see that we can do without greatly disturbing our present accounting, is to deduct the cost of that machine from the surplus account, which would have been lessened had we charged its cost to operating expenses during the time the machine was consumed.

MR. INSULL: Whether you charge it off in one year or covering a period of five years is immaterial. What I want to bring out and impress upon our members is the principle that they have continually charged against the construction account all they have bought year after year, wiping out from their memory at the end of one year what they bought the previous year; and if they, as a result, show large profits because they have refrained from putting into operating expenses things that should go there, they themselves are pursuing a course that must inevitably result in giving arguments to the people that want to upset our business, whether they do it in the way of municipal ownership or otherwise.

Mr. Doherty: I agree with you.

Mr. Insull: The real base of all the troubles of our electric-light companies is a lack of appreciation of what constitutes cost. I think that if we would discuss this subject from that point of view, it would probably result in the appointment of some committee to get up a uniform system of accounting; whether that recommended by Mr. Cahoon, or some other, is immaterial. The results obtained would put us in such a position that, instead of discussing the desirability of publishing our accounts, we should all of us be extremely anxious to publish them, as they would show that there is hardly an electric-light company in the United States to-day that is earning more than interest, and a fair return above that, to justify the risk they take in investing their capital. I have only to take the case of my own company. We pay our stockholders eight per cent, and we have a very good business; but if you will analyze our investment accounts, and figure simple interest on our investment, you will immediately come to the conclusion that the only way in which we can pay more than interest in the shape of a dividend is the fact that we borrow our money a little cheaper than some other companies that are not equally fortunate. That is the reason why most of the large companies are paying dividends of six, seven and eight per cent; the only way in which they are able to do it at the present time is because they are borrowing money at five per cent or a little lower.

As a matter of detail, I notice in the report that there is one item where you reckon interest on your investment and current liabilities. There is no justification for an electric light company's having liabilities of any consequence outside of their investment.

MR. CAHOON: A company may borrow five or ten thousand dollars.

MR. INSULL: You mean a small item like that. As to this interest on investment, I notice that in your balance sheet that goes to an account that you call "interest and discount."

MR. CAHOON: That is divided up pro rata over the year.

MR. INSULL: You charge that against the accounts, and on the liability side of your balance sheet it will be a surplus there.

MR. CAHOON: It is in the nature of an advance charge. The total interest for the year is split up into twelve parts.

MR. INSULL: What will you do with that interest?

MR. CAHOON: It is simply accrued interest, and we pay it.

MR. INSULL: Do you transfer it to your profit and loss account?

MR. CAHOON: Yes, sir.

MR. INSULL: I see in your accounts that you charge interest on your investment.

MR. CAHOON: That is bond interest.

MR. INSULL: I do not know whether you expect a lighting company to earn interest on its investment and carry that on an account that can not be distributed and earn interest for dividends besides. I drew attention to this subject of accounts in my address as president of this association two years ago, and took the ground that if we were publicly controlled we should have advantages in the way of exclusive franchises. The first step in this matter is to take our own members, and, if we can, educate them to a uniform system of accounting, so that they will state in their accounts precisely what their cost is, and stop them, so far as moral suasion will stop them, from working their construction accounts; and if moral suasion will not stop them, if we can get copies of their reports kept on a uniform system of accounting, and bring them up here in the convention and ask them to explain their accounts,—if we could do that it would be the first step toward public accounts. There is not the slightest objection to public accounts. We have everything to gain and nothing to lose by the publication of our accounts. We are not in a business that yields an enormous return on the investment; it yields a comparatively small return over ordinary interest rates as they rule in this country. If we can do anything toward getting our own people to submit their accounts to us here in convention, or to a committee that would report on them, and when some company shows an abnormal profit as the result of "immoral" accounting (fooling themselves), we could get that matter straightened out here in convention, when the real facts were known, that would go a long way toward stopping the agitation of the question of municipal ownership. If we can not stop the agitation of this municipal ownership question, this system of public reports will go a long way toward giving us protection in the enjoyment of our business, and will put municipalities in the position that if they want to go into our line of business they must do it by the exercise of the right of eminent domain, and must condemn our property and purchase it on a fair valuation.

I want especially to impress upon you, gentlemen, that the real trouble in the whole situation lies entirely with ourselves. A city official may see the returns of some company in a town of, say, the second grade. The receipts will appear to be $250,000, and the light is produced for fifty per cent of that amount, leaving profits of $125,000. He will say, "My Gracious! the electric light company is making fifty per cent per annum!" What are the facts? We are in a business in which it is impossible to turn our capital under the most advantageous circumstances, in a city of considerable size, in a period of less than five or six years.

MR. DOHERTY: Ten years.

MR. INSULL: Mr. Doherty says ten years; but that is after using the pump and injecting the water. I am speaking on the basis of a company whose issued securities are all cash, giving a return to the investor and little or nothing to the promoter. In the large cities, if you will deduct the amount of the investment lying idle for future purposes, large purchases of real estate, or a station three times as large as is necessary, or a distribution system capable of taking care of double the business,—an electric light company can turn over its capital in five or six years. As I say, if we put our accounts on such a basis that the public know these things and appreciate the fact that in the large companies, instead of earning fifty per cent, we are not earning more than eight per cent, and in the small places instead of earning twenty-five per cent are not earning more than four per cent, it will put us in a position where we can go to the legislatures of the different states and ask that our accounts shall be publicly controlled, and ask that the accounts of municipally-owned plants shall be publicly controlled; and when they come to control us by state authorities, they will have to give us some protection and put us in a position where we are not going to be interfered with; because the voters, the taxpayers of the city, our customers, will see that the true economy of the operation of this business is not by competition, but by regulated monopoly; and I firmly believe that can be best proved by the publishing in detail of our accounts.

I have made the remark at different times that the public has to pay for any duplication of investment in any public-service business. The more we can educate the people as to our exact position and to the fact that if there are two companies in the same city the interest on the investment has finally got to come out of them, the more solid we can make our investment, and, incidentally, the less chance there will be of municipal ownership; or if it comes—and I see no objection to its coming—I would just as soon have the municipality of Chicago buy out the Chicago Edison Company as any of the syndicates; I do not see that it makes any difference—but if it is to come, it will come in a way that will give us our money back, and a fair return on the risk we have taken.

The larger Edison companies have for a number of years past tried to keep their accounts on about the same basis. The accounts of the New York, Brooklyn, Boston, Chicago, and all of the larger Edison companies are kept in practically the same way, and it would be found, if we should make returns, that our present system would fit into the system of accounting suggested here. We do not happen to carry on our books some of the accounts in the exact form suggested, but it would be very little trouble to do so. These companies started to keep their accounts largely on the same basis for the purpose of comparison—to get a certain rivalry in reducing operating expenses—and we have benefited greatly by it. If this association would take up the matter on a comprehensive scale, and get the various members to keep their accounts on such a basis that they can make reports that will fit in somewhat with this paper—or some other scheme that a committee might suggest—I am sure we should be greatly benefited by such a course. Any company with which I am connected will give the information, and will have no objection to its publication after it is given.

MR. BEAN: I wish to ask Mr. Insull a question. Take, for example, a small plant in the country that four years ago paid $2,000 for a dynamo. This year they want to change that and put in a $4,000 dynamo; how would you charge that off?

MR. INSULL: What was the capacity of the $2,000 dynamo?

MR. BEAN: Say, fifty lights.

MR. INSULL: What is the capacity of the $4,000 dynamo?

MR. BEAN: Say, one hundred lights.

MR. INSULL: What did you do with the fifty-light machine?

MR. BEAN: Sold it for little or nothing.

MR. INSULL: Say you got $250 for it.

MR. BEAN: Very well.

MR. INSULL: You would lose $1,750. I should write that off through a period of thirty months—two years and a half.

MR. BEAN: Why not write it off entirely at one time?

MR. INSULL: I do not see how I could write it off entirely. If I owned the property myself, and had not to distribute the earnings, I would write it off that year.

MR. BEAN: My point is this: I want to say that if I paid $2,000 for a dynamo four years ago, and want to buy another for $4,000, and can only get $250 for the old one, the proper thing is to charge off $1,750 and credit $250 to construction account.

MR. INSULL: If you can do it in one year, you are very fortunate; I cannot do it. The way I would treat that would be to charge it over a period of two years and a half to come.

MR. BEAN: To come?

MR. INSULL: Yes; you cannot charge it against what is closed. Carry it in a liquidation account, or leave it in the investment account and write it off month by month.

MR. NEAL: We have a system of accounting in Massachusetts that we are required to follow, which was devised by the Gas and Electric Light Commissioners. It is a very good method, but it is not comprehensive enough and some items might be added. I spoke to the principal member of that commission some time ago, and told him there were certain matters relating to the rendering of accounts for publication that were defective, and he said that some time, as soon as he had the opportunity, he would look the matter over. It would please me, and I think all the Massachusetts companies, both gas and electric, if every state had a system of accounting very much like that we have. You can read all our returns, and know just what we are doing, and comment on our methods; but we have no opportunity of knowing what the other companies throughout the United States are doing. I wish there was a gas and electric light commission in every state; it would be for the benefit of all.

MR. WEEKS: There is no question in my mind as to the usefulness of a common system of accounts;

one that will enable us all to compare the data of our separate stations intelligently and effectively. Among the early Edison stations we had such a system, to which Mr. Insull has referred, and we found it of great interest and profit. But it has occurred to me that a very serious obstacle would arise in this association to the general use of such a system of accounting, from the fact that many of us represent stations that are owned and controlled by parties having other interests many times larger than their investments in electric lighting. These owners have their peculiar systems of accounting, which they require to be used in their smaller interests of electric light and power. This would, of course, make it necessary for such stations to keep a double system, in order to compare results with other stations, and there is strong probability that many would not go to that trouble and expense in order to secure the advantages of such a system.

MR. F. E. SMITH: There seem to be different ways in charging off the depreciation. A $2,000 dynamo may be sold for $250 after having been used but a few years. Would it not be proper to charge off a certain percentage, beginning with the year you bought the machine, and at the end of the period of usefulness it is off your books? In charging off in that way, there is a question in my mind as to what method we should adopt. Take a small plant, costing at first $300,000. Of course we are adding to it each year. At the end of the first year we may have a plant representing a cost of $310,000. On what basis are we to charge off at the end of the first year, $300,000 or $310,000; and at what rate per cent? Some parts will depreciate more rapidly than others. At the end of the second year we may have

betterments. That is, if a large addition was made, and new bonds issued for the addition, then start with that addition and charge five per cent on that also; but that the ordinary depreciation charge should take care of the minor extensions or betterments. starting with five per cent on the original investment

MR. INSULL: Would you include real estate, et cætera, in that total investment?

MR. CAHOON: Only apparatus.

MR. INSULL: Buildings?

MR. CAHOON: There are many arguments in favor of applying it only to the part of the plant which goes to pieces; moving machinery and buildings.

MR. INSULL: Take an underground system—would you deduct five per cent on the cost of the conduit?

MR. CAHOON: No.

MR. INSULL: Would you deduct five per cent for the cables?

MR. CAHOON: No.

MR. INSULL: Well, then, you are not going to deduct five per cent.

MR. CAHOON: You must consider the particular plant; you must consider your plant, your location, and what you are doing, and then take that factor for depreciation that will equal the total for the term of years over which the life of the apparatus will probably extend.

MR. INSULL: I simply want to bring out what is really meant by five per cent, and what it is on; because I know that, as a matter of fact, no companies represented in this room can stand five per cent on the total investment.

MR. ANTHONY (Chicago): In regard to the

question of uniform accounting and the question of depreciation of which Mr. Cahoon speaks, should not the amount of depreciation, whether two per cent, three per cent, five per cent, depend wholly upon how well you keep up what investment you have? I believe that depreciation is wholly an operating charge. In the first place, if you keep your investment up to a standard of one hundred per cent, and if the cost of the parts renewed is charged off every month against the various accounts that Mr. Cahoon has so carefully prepared in his report, have you not then taken care of your depreciation in the very best possible manner in which one can take care of it?

MR. CAHOON: Precisely.

MR. ANTHONY: I doubt if the earnings of any electric light company in this country could possibly stand a charge of five per cent each year on the investment, and give the stockholders anything. If the machinery is kept up to such an extent that there is practically no depreciation except where you change capacity, and that change in capacity is taken care of in the way suggested by Mr. Insull and the other gentlemen, the matter is very simple. I say, write off depreciation effected by changes in capacity against one year if the earnings can stand it; but if not, extend it over a proper period of time. I do not believe one year should be obliged to stand all this change in capacity depreciation, and thus be made an unproductive year. The only difference on the subject is a question of opinion as to the period of time over which the deduction should extend; and of course that is a matter that must be regulated to each individual case.

Uniform accounting is a necessary adjunct to the business of the various companies, and every attempt should be made toward obtaining such accounting so that we can all understand each other; and the figures should explain themselves, with no need of an expert bookkeeper or accountant to explain them. The headings and columns, and the way they are put, should be their own explanations, so that "He who runs may read." I believe, also, that the accounting should be done as nearly as possible on a bank basis, that we may know from day to day and week to week what we are doing, and not wait until the 25th of the succeeding month to find out what mistakes were made the previous month. Then we shall have a system that tells the electric lighting company something, one that may serve as the starting point for a uniform system of municipal accounting as well.

MR. CAHOON: It may be well to read again a paragraph or two on this matter of depreciation:

"If we do not charge off each year, and expend as an investment in renewals and minor extensions and betterments a certain portion of the original investment, the time comes in the course of seven or ten years when we have to borrow thousands and thousands of dollars to renew the plant, and it may be at a time that will be very inopportune. The best policy for ourselves, laying aside the whole question as to whether or not it is better as a source of protection from the public, is to recognize this factor, and include it in our cost of operating expenses.

"A certain depreciation, determined on by experience, varying according to location and according to class of manufacture, we find will occur every year. Let us take, then, the yearly proportion on the basis of lasting so many years, and place it each year under the head of investment insurance, and use that in our business for minor extensions and betterments and renewals sufficient to keep our plant intact and in as good operating condition as when first purchased; or, in other words, maintain our plant in such a manner that if a question of being compelled to sell it comes up we can show that we have maintained it in such a way that the original investment is not impaired in the slightest:"

You can get at it in that way, or can now find by experience what the life of the apparatus is, and, taking the value of the year's proportion, set aside that sum as an investment and use that in the plant. In regard to the other point, of knowing all the time where you are at, I find that with this system of accounts we can in a very few minutes ascertain daily just what we are doing; keeping what may be called a running balance all the time. I was called upon on one occasion to prepare a statement in fifteen minutes, and had no difficulty in doing so with this system of bookkeeping.

MR. WALBANK: The company that I represent is comparatively a new one. The question of depreciation, and the amount that should be set aside to provide for same, was discussed at our last meeting. Shareholders, as a rule, are very averse from laying aside anything for depreciation, and consider that a plant will not depreciate when it is new.

Our plant is a water-power plant, consequently we have no boilers, steam engines, belts, and the like, to depreciate; but we have dams, water wheels, governors, shafting and line construction, which will depreciate more or less.

I do not approve of the system of writing off an amount to depreciation; in lieu thereof, and which practically amounts to the same thing, is to estimate what the probable depreciation would amount to, and set it aside under the heading of, say, contingent account. I consider a good large contingent account, set aside, year by year, preferable to writing off from your capital for depreciation. For this reason: If each year you should write off a certain percentage on the value of your plant, at the end of a given time your books would not show your plant to exist. If a fire should take place, you would not be able to show as large a plant as you pretended to have insured. I consider it is better to keep your plant fully maintained, and all repairs charged to operating expenses as you go along, adding yearly as good a sum to the contingent account as you find at the end of the year you can afford. Do not pay too big dividends at the commencement; and any improvement, betterments or replacements that it may be necessary to make to the plant should be charged to operating expenses, and the difference between the value of the part to be replaced or improved and the cost of the new plant should be charged to the contingent account. I fully approve of having a uniform system of accounting, and agree with Mr. Insull that it would be the best way of settling the question of municipal control.

MR. SCOVIL: I think Mr. Doherty made a good point in the opening of his remarks when he said that if we went into the discussion of a uniform system of accounting we should never get through. I think the discussion has a tendency to drift off somewhat into other things than accounting. I move, therefore, that the following resolution be adopted:

Resolved, That it is the sense of this association that the president and executive committee of the association appoint a committee to formulate a system of uniform accounting, and that this committee shall proceed with its work as promptly as possible so as to put the system of accounting to be recommended by the committee, in printed form, into the hands of the members of the association so that they can intelligently discuss it at the next annual meeting of the association.

The motion was carried.

The meeting then adjourned.

FOURTH SESSION.

President Carnes called the meeting to order at half-past two, and announced a paper by Professor William Lispenard Robb as the first order of business for the afternoon session.

Professor Robb presented the following paper:

SERIES INCLOSED ALTERNATING ARC LIGHTING FOR STREET LIGHTING SERVICE

For a number of years previous to 1896 the arc lamp and arc-light dynamos remained practically unchanged, and most of us were disposed to consider this class of apparatus as having practically reached the stage of final development. No class of electrical apparatus has, however, undergone more radical changes during the past four years than that used for arc lighting. These changes have been brought about by the consolidation of numerous small plants, making it advisable to supply large areas from a single central station, by the introduction of the inclosed-arc lamp and by the fact that the inclosed-arc lamp made possible the successful use of the alternating-current arc lamp.

The inclosed-arc lamp on constant-potential circuits has now been in successful operation for about four years. The series inclosed arc has been in equally successful operation for a period of two years. The superiority of the inclosed-arc lamp has been appreciated by the general public, both when applied to interior lighting and when applied to street lighting. This superiority is not due to a greater mean spherical candle-power, this being undoubtedly very much greater in the open arc than in the inclosed arc when both are supplied with the same amount of energy. The superiority is due, rather, to the greater constancy of the light and its better diffusion, and to the relatively greater life of the carbon and the consequent infrequent trimming of the lamps.

In all long-distance transmissions of electricity, and when large areas are supplied from a single advantageously located power plant, we must, at least in the present state of the art, generate and transmit alternating current. In general, it will, in my opinion, especially if the wires are underground, be found desirable to supply the current to the street lights from the same secondary mains that supply the current for commercial lighting and power. This means that where low-tension secondary mains are in a street, we should do our street lighting with constant-potential inclosed, alternating, or direct-current arc lamps, the kind of lamp used depending on the kind of current used on the commercial circuits. There are, however, in all places, large areas in which the streets are lighted by arc lamps, and where there is no commercial lighting or power. These sections can be most economically lighted by series arc lamps.

Various methods of operating series arc lamps from alternating-current generating systems have been suggested, and are now in successful operation. These systems may be grouped as follows:

First—Synchronous or induction motors can be used to drive a line shaft, from which are belted the series direct-current arc dynamos that supply current to either open-air or inclosed direct-current series arc lamps.

Second—Direct-current series arc dynamos can be direct-connected to either synchronous or induction alternating-current motors, and the dynamos used to supply current either to open or inclosed direct-current series arc lamps.

Third--The constant-potential alternating current supplied by the generators can be transformed directly by rectifiers into a constant-current direct current, and used to operate either series inclosed or open direct-current arc lamps.

Fourth—Series alternating inclosed-arc lamps can be connected in series, with a reactive coil across the constant-potential alternating-current circuit.

Fifth—The constant-potential alternating current supplied by the generators can be transformed directly by constant-current transformers into constant current, and used to operate series inclosed alternating-current arc lamps.

I have not included in the possible systems that in which the series arc-lighting system is operated by its own steam plant, as it is practically the unanimous opinion that, with the present condition under which central stations operate, the best results are obtained when one kind of current is generated and this is transformed for the various kinds of service required.

The history of the electric-lighting industry during the past two years seems to have demonstrated that in practically all sections of this country it is possible to replace the open-air arc with inclosed-arc lamps, and give equal, or better, satisfaction when the same amount of energy is applied to each type of lamp. As the annual saving per lamp in trimming, carbons, inspection, and maintenance of the lamps, is approximately ten dollars, it would seem to place the open-air arc out of consideration, and the question of street-lighting system resolves itself into which of the above-mentioned systems should be adopted for operating inclosed-arc lamps.

The system of street lighting that will be found best for any given city undoubtedly depends largely upon local conditions. But there are undoubtedly many cases where investigation will show that the adoption of the constant-current transformer and the series alternating inclosed-arc lamp will at present offer the best solution of the problem.

President Carnes kindly requested me to prepare a paper embodying the results of our experience with this system in Hartford, where constant-current transformers have now been in use continuously for more than two years.

We are at present operating 804 street lights. Seven hundred of these are operated from constant-current transformers on series alternating-current circuits. The remaining lights are operated from a constant-potential Edison three-wire system. Eight constant-current transformers, each of 100-light capacity, are in use. Six of these have been installed in two transformer houses, at a distance from the central station, and are operated without any attendant.

The construction of the 100-light transformers is shown in Figures 1 and 2. In transformers of smaller capacity there are but two coils, one fixed, and one movable, as shown in Figure 3.

Each transformer is inclosed in a cylindrical tank. The tanks were originally made of boiler iron riveted up. It proved impossible to keep tanks made in this way tight against the transil oil in which the transformer is immersed. The tanks are now made of cast-iron.

The core of the transformer is of the sheet type, with a large central vertical core rising the whole height of the tank. This central core is surrounded by primary and secondary coils, and the magnetic circuit is closed by return paths outside the coils. One of the primaries is fixed at the bottom and the other at the top of the central core. The two secondaries are free to move up and down between the primary coils, and are so connected that when one falls the other rises. They may approach into contact with each other at the middle of the tank, or from this position one may rise toward the primary coil at the top, while the other falls toward the primary coil at the bottom. Connected with the chains by which they are balanced, is a lever, which extends outwardly from the top of the oil tanks and carries, suspended from its outer end, an adjustable weight. The lever is supported on a hardened-steel knife edge. The

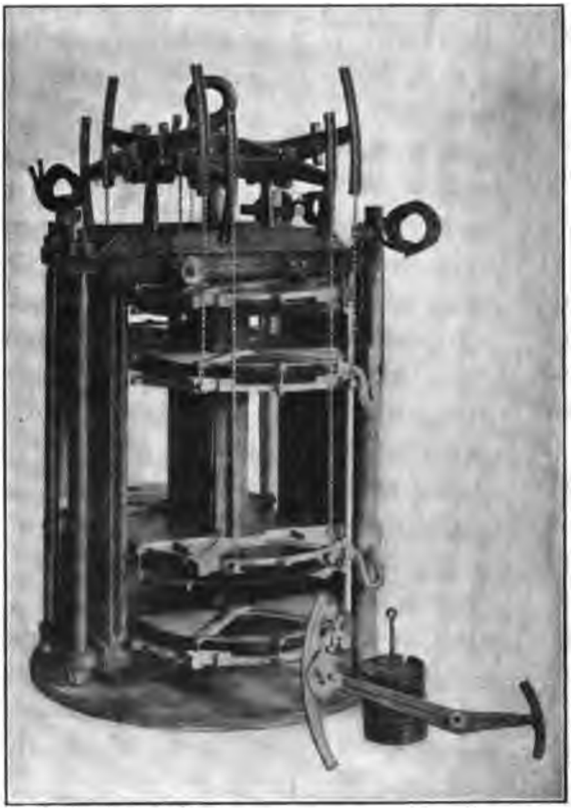

FIG. 1.—100-LIGHT CONSTANT-CURRENT TRANSFORMER.

weight tends to force the two secondary coils respectively toward the two primary coils. When the transformer is in operation the currents induced in the secondary react upon those in the primary, and tend to force the coils apart. This force is balanced for the desired normal current by the adjustable weight outside of the tank. The 100-light transformers are arranged to operate two circuits of fifty lamps each. The circuits are connected upon the multi-circuit principle first used with the Brush series dynamos.

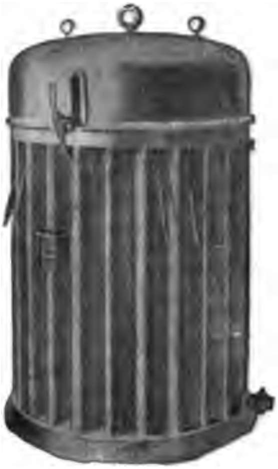

FIG. 2.—CASE OF CONSTANT-CURRENT TRANSFORMER.

The transformer can be adjusted so as to give practically constant current from one-third load to full load. The regulation below one-third load is sufficient to prevent the current from rising to an extent that will endanger a single lamp if all the others should be cut out.

The first lamps were trimmed every five days, but since adopting the caps now in use it has only been necessary during the long lighting hours of winter to trim once in six days. The trimming is taken care of by two trimmers, and from the results obtained we find that one trimmer, with horse and wagon, can easily take care of five hundred lamps. This would make the annual cost of trimming per lamp, at the Hartford rate of wages, two dollars per lamp, as against eight dollars, which was the cost per lamp when the open-air arcs were used.

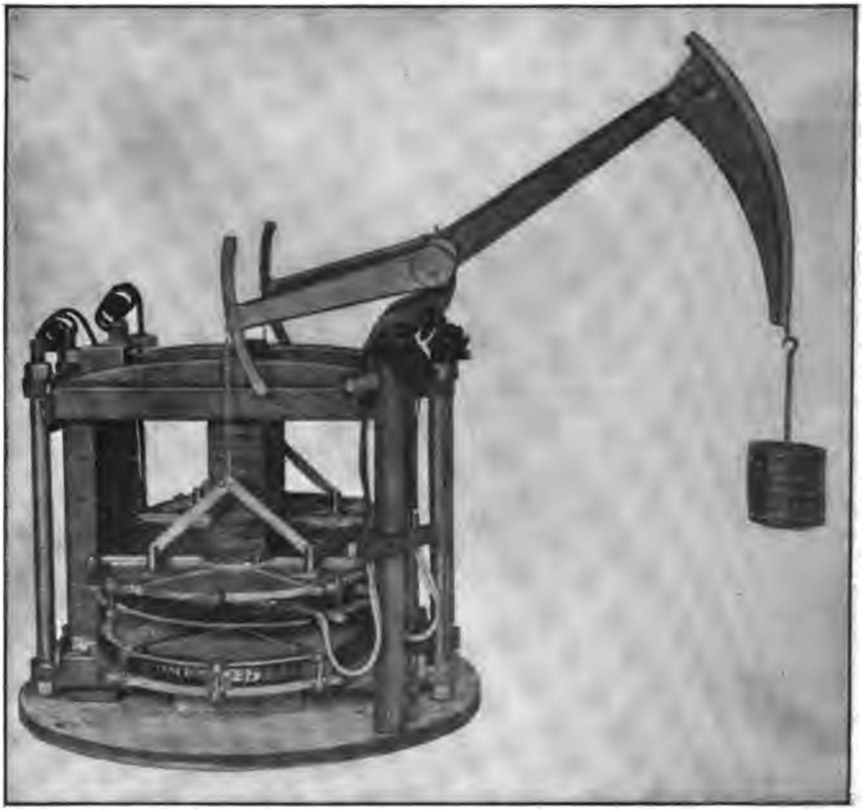

FIG. 3.—50-LIGHT CONSTANT-CURRENT TRANSFORMER.

The cost of carbons per lamp per year is $1.50 per lamp against $5.84 previously paid for open-air arcs.

The cost of inspection has remained unchanged.

The cost of inner globes now averages less than two globes per lamp per year, or about thirty cents pei lamp. Both the breakage of outer globes and the repairs on the lamps have been considerably less, but the data accessible are not sufficient to permit me to state this saving exactly. The annual saving in trimming, carbons, and repairs made by replacing the open-air arcs with inclosed arcs has undoubtedly been greater than ten dollars per year per lamp. The service has been improved; the number of hours lights have been out has been reduced about fifty per cent. During the past six months the records show that out of 804 lamps, the "outages" amounted to 2.2 lamps out all the time. The service furnished by the inclosed-arc lamps has been extremely satisfactory to the public and to the Board of Street Commissioners having charge of the street lighting. This Board in their last annual report just issued took occasion to refer to the extremely satisfactory condition of the service, and made especial reference to the small amount of "outages."

In most of the tables that have been given, showing the comparative expense of operating the inclosed and open-arc lamps, the breakage of the inner globes is usually stated as much larger than we have obtained in our actual experience. This, I believe, is due to the experience that the trimmers have gained, as the breakage has materially decreased during the past year. During the past month the rate at which cylinders have been renewed has been about eight-tenths of a cylinder per lamp per year. The smallness of the renewals is also in great part due to the fact that the cylinders are cleaned every time the lamps are trimmed, and consequently can be cleaned with a brush and hot water, and no acid is required for removing the deposit.

The success, or failure, of the introduction of inclosed-arc lamps depends largely on whether the cylinders are kept clean. They should undoubtedly be cleaned every time the lamp is trimmed, and not at the lamps, but at the central station.

The transformers and arc lamps were made the subject of careful tests, and the results of these tests have been embodied in a paper already read by the author before the American Institute of Electrical Engineers.* The average results obtained from two 100-light transformers, are as follows:

Load	Efficiency	Power factor
1/4	88.1	24%
1/2	92.3	44%
3/4	94.9	62%
Full,	96.1	78%

The rise in temperature of the oil in the transformer measured, at the top of the iron core where it is greatest, 39 degrees C. after twenty-four hours' run.

Under the usual conditions of street lighting the dynamos at all times carry at least ninety per cent of the full load, and at this load the efficiency and power factor of the constant-current transformer alternating system are satisfactory. The power factor is approximately the same as that obtained with induction motors at the average load at which they are operated. The low power factor at fractional loads makes the use of a constant-current transformer undesirable when the conditions are such that the transformer is not operated at a large part of its rated full load.

It has been found in practice that the transformers

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*Meeting held September, 1899. Paper reprinted in the *Electrical World* and *Engineer*, November 4, 1899.

can be maintained and operated successfully with little attention. At Hartford, six .of the transformers have been operated during the entire past year from two outlying substations. There is no attendant at either of the stations. The inspector of the district cuts on and off the lights at the proper time and visits the substation once during the night. Each transformer is equipped with a recording Bristol ammeter, so that a complete record is kept of the time of cutting on and off the circuit, and of the time the inspector makes his nightly inspection, and of the working and adjustment of the transformer. We have a complete daily record of the operation of the transformers since their installation, and I have with me a large number of these records that demonstrate how perfect the regulation of the constant-current transformer is, even when operated from substations without any attendant. Although the voltage at the terminals of the primary of the transformer is subject to a variation of several per cent during the street-lighting hours, the current supplied to the series lighting circuit is practically constant. The records that I have with me record the operation of transformers located in a substation about a mile from the central station. These transformers take their current from the feeders that supply the commercial lighting and power system. We have had no single interruption in the service due to the fact that the transformers are operated from transformer-houses, with no attendant in charge of them.

The lamps that have been used in Hartford are of the carbon feed type, and differential. The power factors, as given in the above table, were measured on the primary side of the transformer, with differential lamps on the secondary. The power factor would be considerably increased if satisfactory shunt lamps were used. Lamps of this type, however, with which I have had the fortune to experiment, have not proved satisfactory when compared with the differential lamp, and it was considered that the differential lamp was a better one to use, even if its use reduced the power factor of the system several per cent.

The following brief comparison of the series inclosed alternating-current arc lighting from constant-current transformers with the other systems of series-inclosed arc lighting suggested in the earlier part of the paper, may prove interesting. In making the comparison between the different systems, I have assumed, and believe it to be true, that equally satisfactory results in street lighting can be obtained from the 6.6-ampere inclosed direct current, and the 7.5-ampere inclosed alternating-current arc lamps. The comparison is confined to these two lamps under full-load conditions, as in series street lighting this is the usual working condition.

First. Comparison of system using direct-current arc dynamos, belted from a line shaft driven by motor.

Actual experience in the Hartford case showed a saving in power of 150 watts per lamp, when 400-watt alternating-current lamps supplied from constant-current transformers replaced nominal 1,200 candle-power open-arc lamps. This, assuming the value of power at the switchboard as one cent per kilowatt-hour, would mean an annual saving in the cost of power of six dollars per lamp per year in favor of the constant-current transformer system. The saving of space in the central station has been very considerable, the space occupied being not more than one-tenth as great as the space formerly occupied by the line shaft and arc-light dynamos. The repairs on shafting and belting are entirely eliminated, and the maintenance and repairs on the constant-current transformers very materially less than the repairs and maintenance of the arc dynamos and motor, and the services of an attendant have been dispensed with.

Second. Comparison with system using direct-current arc dynamos, driven by induction motor.

The combined efficiency of the induction motor and series arc generators is approximately eighty per cent. The power factor of the induction motor is ninety per cent. The efficiency of the transformer is ninety-six per cent, and the power factor of the entire system, seventy-eight per cent. The number of watts supplied to the lamps is approximately the same. By the use of the alternating system there is consequently a saving in actual power and load on the engine of eighteen per cent, and in apparent load, and consequently in the capacity of the generators, of about ten per cent.

On a thousand-light equipment one attendant would be required to look after the arc-light generators, whereas the amount of attendance required by the constant-current transformers is apparently negligible. This makes possible the placing of the constant-current transformers in a sub-station. This frequently greatly simplifies the wiring system. In the case of a central station operating 1,000 lights in half a dozen neighboring towns, careful estimates were recently made of the relative cost of the wiring system if the lamps were operated from motor-driven arc dynamos placed in the central station, and if operated from constant-current transformers placed in the transformer houses in various towns. There was found to be a saving in the first cost of the installation of the wiring system of $11,000 in favor of the constant-current transformer system. Constant-current transformers take up only about half the space of the motor-driven dynamos; the initial cost of the transformer is much less than the cost of the motor-driven dynamo, and the repairs and maintenance are also less.

Third—Comparison with series alternating arc lamps, operated in series with a reactive coil.

If the reactive coil and arc circuits are placed directly across the 'bus-bars, they introduce the grounds on the series arc circuits on the general system, and also limit the series arc circuits to a comparatively small number of lights. This will, in general, make it advisable where this system is used to introduce step-up static transformers between the 'bus-bars and the series arc lighting circuits. These transformers serve the double purpose of removing the arc-light grounds from the 'bus-bars, and also make it possible to increase the number of arc lights operated on each circuit. Other things being equal, it is of course preferable to have the transformer and reactive coil combined in one piece of apparatus, as it is in the constant-current transformer.

If the reactive coil is installed with step-up transformers and is installed with sufficient capacity to protect the lamps at all loads between no load and full load, the advisability of adopting one of the alternating systems rather than the other will depend largely on the relative reliability of the lamps furnished with the two systems. The series differential alternating lamp has now stood the test of actual service for two years, and is able to fulfill the requirements of a satisfactory lamp. It is to be hoped that a shunt lamp will be made that will do the work equally satisfactorily, although it seems extremely doubtful if a shunt lamp can be made to work on series circuits as satisfactorily as a differential lamp. The use of the shunt lamp would mean a very material increase in the power factor of the alternating series arc lighting systems.

Fourth—Comparison with system using series inclosed direct-current arc lamps, supplied with current from rectifiers.

In this country, up to the present time, it has been impossible to manufacture satisfactory rectifiers intended to operate on a frequency of sixty cycles. It is considered practicable, however, to make rectifiers that will operate at twenty-five cycles. Even if sixty-cycle rectifiers could be made to operate satisfactorily, it is doubtful if they could compete with the constant-current transformer, as in addition to the constant-current transformer, they would have complicated rectifying devices, and would require the services of an attendant.

With twenty-five cycles it is impossible to operate alternating-current arc lamps. The constant-current transformer system could consequently be used only in connection with frequency changers. Consequently, when central stations operate at low frequency, the introduction of rectifiers will be advantageous, the advantages of the rectifier over the system in which series arc dynamos are direct-driven by motors being in many respects the same as the advantages of the constant-current transformer over the same system.

I venture the prediction that in the near future in the great majority of the cases where alternating current is generated, if the frequency is sixty cycles to the second, the series arc lighting will be by series inclosed alternating arc lamps, and if the frequency is twenty-five cycles the series arc lighting will be by direct-current inclosed arc lamps, supplied by current from rectifiers.

It is to be hoped that this paper will serve to open up a discussion in which the merits and faults of the various systems of series arc lighting will be fully brought out by those who have had actual experience with the different systems.

DISCUSSION.

MR. WAIT (Chicago): I should like to ask Professor Robb a question. In his paper he speaks of the annual cost of trimming as two dollars per lamp. I would ask if that includes the cost of the horse and wagon and also the cost of the cleaning in the stables.

PROFESSOR ROBB: Yes, sir.

MR. WAIT: Then one man trims eighty-three lamps a day, and cleans the globes in the station?

PROFESSOR ROBB: The same man does not clean the globes. An office boy cleans them in the morning in a few minutes; but that is included in the cost.

MR. WAIT: I notice on one page the statement that the number of watts supplied to the lamps is approximately the same, and on the preceding page the statement is made that the writer assumes, and believes it to be true, that equally satisfactory results in street lighting can be obtained from the 6.6-ampere, direct-current, inclosed-arc lamp and the 7.5-ampere, alternating-current, inclosed-arc lamp. These two statements are approximately equivalent; that is, the 7.5-ampere after being multiplied by the power factor will make approximately 450 watts in either case.

PROFESSOR ROBB: It is meant to be so.

MR. WAIT: Then these comparisons are based on the assumption that an alternating lamp with 450 watts will give as good street illumination as a direct-current lamp of 450 watts, inclosed arc. This brings up the subject on which the committee reported yesterday. I happen to have gone through some of the figures in the report and worked out the results, and to those that have not done so it may be interesting to know that the average watts per mean hemispherical candle power in the alternating lamps reported on is greater by twenty-six per cent than the watts per mean hemispherical candle power in the direct-current lamps reported upon. I also took the average of the illumination from the horizontal to twenty degrees below. The efficiency of the direct-current lamps reported on is about twelve per cent greater than that of the alternating lamps at these same angles. In comparison with these figures it might be interesting to note the curves on page 275 of the June issue of the *American Electrician*, which has been passed around the hall. These curves are made up from the averages of quite a number of other averages. The direct-current lamps exceed the alternating lamps in efficiency by thirty-three per cent in the watts per mean hemispherical candle power, while between the angles of zero and twenty degrees below the advantage of the direct-current lamps is twenty per cent. As stated, these curves are made up from the results of a large number of published reports, and also some tests made in the laboratories of two large manufacturing companies, which tests have not been published; so, although they may not be quite as accurate as the investigations of the committee, they perhaps show the general type of the curves better than those in the report, as they are the average of a number of different methods of measuring the illumination made by different observers at different places. Of course, if either of these values were used instead of taking the lamps on an equal basis, as in Professor Robb's paper, the conclusions would be considerably affected, and perhaps the decision reversed in some cases.

In continuation of the question of street illumination taken up yesterday I should like again to call the attention of the association to the importance of establishing some basis of specifying street lighting, on account of the danger of the electric light companies throwing away their business to the gas companies by specifying the minimum illumination.

A few figures on this question may be of interest. In an article read before the American Institute of Electrical Engineers on December 27th there are some curves of the intensity of the illumination at the street surface with different kinds of arc lamps, and also incandescent lamps, differently placed. One of these curves (Figure 14) shows two arc lamps fourteen feet high, consuming 450 watts each, placed 300 feet apart. Superimposed on this is another curve showing the light from three clusters of incandescent lamps, with 100 candle power of incandescent lamps in each cluster, the clusters being 150 feet apart, which is twice as frequent as the arc lamps. In these curves the light between the posts only is shown. If a whole row of lamps of each kind had been taken, and 450 watts allowed for each 300 feet for each of the systems, the efficiency corresponding to the incandescent-lamp curve would be 2.25 watts net per mean hemispherical candle power. This figure might be obtained, for example, by the use of three-watt lamps and a reflector, which would save one-third of the light otherwise being in a large measure lost in the upper hemisphere. The arc-lamp curves are made up from some curves made by Professor Matthews and given in a paper read before the American Institute a short time ago. The curve representing the street illumination from two 450-watt, direct-current lamps with opal inner globes gives a minimum of .034 candle foot. The incandescent lamps give a minimum of the same value. For the purpose of present consideration, the cost of delivering the watts at the incandescent lamps and the alternating arc or the direct-current arc will be approximately the same; that is to say, the difference will not be comparable with the great difference that we get between the illumination. The means of these two classes of lighting are .18 candle foot for the direct-current inclosed lamps and .14 candle foot with the incandescent lamps. In other words, the efficiency of lighting by incandescent lamps is just about the same as with direct-current, inclosed-arc lamps with opal globes at this distance apart. Professor Matthews has since stated that he does not think either the direct-current or the alternating-arc lamps used in the above curves gave quite as high efficiency as they might have done, and the efficiency obtained in the tests for his present report do show a higher efficiency. Taking the alternating lamps on these same curves, the minimum is .015, or about half of the other two. The mean is .051. In other words, the alternating inclosed lamps tested at that time by Professor Matthews do not compare in efficiency for street lighting when either maximum, minimum or mean values are specified for lamps 300 feet apart.

It is interesting to note that in the report presented yesterday the watts at the arc per mean spherical candle power of the alternating lamps reported upon is 2.45 with the clear globe and three watts per mean spherical candle power with the opalescent outer globe. Thus we find the efficiency of the alternating lamp is about the same as that of the incandescent lamp; which, in a general way, confirms what I have just said, bearing in mind that the decrease in light with the square of the distance aids the showing made by the incandescent lamps.

If the minimum values of the street illumination are placed lower than they would be with lamps 300 feet apart, the comparison is less favorable to the arc lamps. For example, taking two arc lamps 600 feet apart (these curves are also shown in the American Institute paper, Figure 15), we find the minimum values for the direct-current inclosed lamps are .007 candle foot. For seven bunches of incandescent lamps, with fifty candle power in each bunch, the minimum value is .037 candle foot. If, as in the other case, we consider a whole row of lamps and allow 450 watts for each 600 feet, the efficiency corresponding to the incandescent lamp curves would be about the maximum that we can conceive for the present form of lamps and for a reasonably permanent reflector. The net efficiency per mean hemispherical candle power would then be 1.5 watts. We could obtain this with a 2.7-watt lamp and an eighty per cent reflector; or we could get about the same values by using three-watt lamps with the eighty per cent reflectors, but placed ten feet instead of fifteen feet high. In other words, with the same watts expended we get a minimum value five times as great by the use of incandescent lamps of this high efficiency as we do with direct-current inclosed arcs, while at a net efficiency that could readily be obtained with the apparatus now at hand we should get a ratio of about three to one. With the alternating inclosed arcs the minimum value is along in the same scale as the direct-current inclosed arcs; that is to say, it would be about three to five times as cheap to do a specified *minimum* lighting *of that low value* with incandescent lamps as with the arc lamps.

If we go back to the *mean value* of the street illumination, we shall find that the mean value of the direct-current lamps is .10 candle foot, the incandescent lamps .11 candle foot, and the alternating lamps only .036 candle foot. That is, if we have lighting specified by *mean value*, direct-current lamps can compete with incandescent lamps at values of one-tenth of a candle foot for the *mean value*, but the alternating lamp, with considerably lower efficiency for the hemispherical output, does not compare so favorably on that same basis. For with alternating arcs and incandescent lamps at the efficiencies and distances given in the curves, it will cost nearly three times as much to furnish the same *mean value* with alternating lamps as it will with incandescent lamps or direct-current inclosed arcs, or about twice as much at the common efficiencies.

The foregoing is brought up mainly to point out the danger of competition with Welsbach lighting, and to bring out the point that all electric light associations and electricians generally should avoid the tendency, which seems prevalent now, of drifting toward specifying minimum street illumination. It would appear to be desirable if the committee that reports on the standardization of arc lights could take up this question also, and make some recommendation of what would seem desirable in specifying the lighting of a city; that is, whether maximum, minimum, mean, or some other value, of street illumination should be specified.

In the report of the committee, all the lamps tested had opal or some other kind of absorptive inner globes. The absorption of these globes is quite a considerable factor, say twenty to thirty per cent. This factor alone is sufficient to make quite a difference where the mean illumination of the street is specified; and it would seem desirable that some report be made on the relative illuminating value of the lamps entirely independent of the density of the globes.

In Professor Robb's paper, some of the elements of comparison of direct-current inclosed lamps and alternating-current inclosed lamps are left out. It is quite general in practice to find that the life of the carbons in the alternating lamps is less than in the direct-current lamps, differing, of course, with the make of the lamps. This is sufficient to affect the cost of trimming and the cost of carbons quite materially. Of course, the cored carbons in the alternating lamps cost somewhat more than the direct-current carbons, and, in addition, the core seems to increase the coating of the globe. Professor Robb makes a comparison of the constant-current transformer for series alternating lighting with the inductive regulator system for the same service. The comparison is not carried out very fully. There are no great differences between the two systems; the principal one being that with the inductive regulator system it is possible to get a power factor of eighty-five to ninety per cent, thereby effecting a considerable saving in the cost of the lines and the generating and transforming apparatus. With the static step-up transformer on the inductive regulator system, the troubles from grounds are avoided, and the combined cost of the inductive regulator and the static transformer is considerably less than that of the constant-current transformer; so that in certain respects the inductive regulator system has advantages over the constant-current transformer system.

MR. TURNER (Cleveland): Last fall, I visited Hartford to inspect the street lighting. After riding along several streets lighted by both systems, my conclusion was that the streets lighted by alternating-current lamps were better illuminated than those lighted by direct-current lamps. A photometer test in which candle power only is determined, is not the best test of a lamp for street use. The illuminating value of the lamp is the correct value to ascertain, and this can probably be best done by an inspection of lamps in actual service on city streets. On a street in Cleveland we hung six lamps on two spans 300 feet apart. On one span wire, two alternating-current, inclosed-arc lamps and one direct-current open lamp were hung; on the other span wire, two direct-current open lamps and one direct-current inclosed lamp were hung. All lamps were adjusted to 480 arc watts; the alternating-current lamps were fitted with tin shades; separate switches controlled each lamp.

One evening, about thirty delegates to the Ohio Electric Light Convention inspected this exhibit. Previously to doing so, nearly all had declared themselves in favor of the direct-current inclosed lamp for street lighting. Subjecting the lamps to all the usual street-illuminating tests, after two hours all but two of the delegates were convinced of the excellence of the alternating-current lamp. Soon after this we hung fifteen multiple, alternating-current inclosed lamps on a business street. The lamps were suspended from poles alternated from side to side of the street and placed about one hundred and fifty feet apart. Attention has already been called by others to the comparatively large loss of light above the horizontal in the alternating-current lamp. This factor of the lamp we took into consideration. We put large reflecting shades on each lamp, and took particular care to hang the lamps at such a height as to give the best illumination for the distance the lamps were apart. Both clear and opal inner globes were used, and I am certain that the best illumination was obtained with the opal inner globe; the diffusion of light was better, and at a distance of seventy-five feet, or midway between the two lamps, the candle power was greater. This fact, that light passed through opal glass at certain angles may be stronger than if passed through clear glass, is a point of considerable value, as it enables us to obtain a far superior illumination where lamps are sufficiently near together. This one street in Cleveland lighted by alternating-current lamps is lighted as well as any street I have yet seen. During the time these lamps have been in operation there have been no unfavorable remarks from the city authorities.

MR. SMITH (Somerville, Mass.): I would ask Professor Robb how many kilowatts he finds a 100-light tub to consume at full load.

PROFESSOR ROBB: About 42.5 kilowatts on the primary side of the transformer when 6.6-ampere lamps are used.

MR. NEAL (Charlestown, Mass.): I am much pleased with this paper presented by Professor Robb, and I am glad to hear the remarks on the paper, because the latter part of last year the Charlestown

Gas and Electric Company made a contract with the city of Boston at thirty-five cents a night per arc lamp, to burn all night and every night in the year. It is in the contract that we shall substitute the inclosed arc for the direct-current arc, and now the question comes, shall it be the alternating or the direct-currrent? I have consulted a good many experts in the East, and I am advised by all means not to use the alternating current. I have heard at this meeting some very good reports from some of the western companies that the alternating current is the best for street lights. The Boston Electric Company, of which Mr. Gilbert, who is a member of this association, is president, made a contract with the city for ten years, starting with thirty-five cents per lamp per night with a sliding scale, the price to be diminished as the number of lamps increased, and I have been told that the saving is very great. With the new lamps there is a saving in the carbons and a great saving in the trimming. It is stated that one man with a horse and wagon can take care of a very large number of lights. I am advised to make the change without waiting for the time required by the contract. I question which is the best method. I think that Mr. Gilbert and those associated with him would advise the direct current to be used, and not the alternating.

PROFESSOR ROBB: He had no choice at the time he made the contract; this system was not in use at that time.

MR. HINE: With reference to the statement as to what is being done by the Boston Electric Light Company, the president of that company told me he had substituted 300 inclosed arcs for the open arcs at a saving of $10 per lamp per annum. That was his experience as far as he had gone in the substitution of inclosed direct-current lamps for the open arcs. He also said that, owing to the method he had adopted for trimming and cleaning the inner globes, one man with a horse and wagon could take care of the entire 300 lamps.

PROFESSOR ROBB: Mr. Gilbert has only three or four trimmers on 2,500 lamps, and each trimmer takes care of something over 600 lamps.

MR. HILLMAN: The Utica Electric Light Company has had some of these arc lamps in use for a year or eighteen months. The statements they have made from time to time are that the saving is $9.74 per lamp per year as compared with the open arcs. I have made this statement to general managers, and some of them have doubted it. They question, for example, that for $1.28 per lamp per year you could trim the lamps, and included in that figure is $15 to $20 per month for horse and wagon. Mr. Sweet, during the eighteen months that these lamps have been in use, has gradually dropped a number of trimmers, and during last winter and spring has trimmed 600 lamps with one man. In the arc lamp department there has been adopted a revolving brush, operated by a motor, for cleaning the inner globes. Some few days ago his trimmer came into the office in the afternoon after having trimmed 125 lamps. He took a box containing 125 dirty globes out of the wagon into the globe department, placing them near the sink for cleaning. This is done by simply pushing the globe over this revolving brush, cleaning and cleansing it at the same time. After this the globes were dried and polished, the globe-holders again placed upon them, and they were carried to the wagon for trimming the next day. The process of cleaning the 125 inner globes was completed in an hour and twenty minutes. I feel that the close attention paid to details in that station is the reason why they can trim for $1.28 per lamp per year, and why they have made a saving of $9.74 per lamp per year in the maintenance account.

MR. WHITE: The apparent discrepancy spoken of is not a discrepancy at all in comparing the wattage of the lamps. In one case, a 6.6-ampere, direct-current, was compared with a 7.5-ampere alternating, both inclosed lamps; and in the other case the 6.6-ampere direct-current is an open-arc as compared with a 6.6-ampere alternating inclosed, with a difference of about twenty-five volts at the arc, which takes care of the point mentioned. On the question of hemispherical candle power, we ought to leave that out entirely in our consideration of the street-lighting problem. It is possible to conceive of one lamp giving twice the hemispherical candle power given by another lamp and yet being inferior in its street-lighting qualities to the other lamp. We do not care a snap about the hemispherical candle power for street lighting; we want a lamp that will give a uniform illumination along the street to be lighted, and the less intensity of light under the lamp the better. You can not get a lamp that will give too small a light under the lamp if it is a lamp that will give a large light at the average distances between the lamps. The great majority of street-lighting lamps in this country will average 500 to 600 feet apart, leaving out of consideration the principal streets in large cities, and therefore we want a lamp that will give the minimum illumination under the lamp and the maximum illumination at distances of 200 to 300 feet from the lamp.

A comparison has been made between street lighting with arc lamps and with incandescent lamps, respectively, and an advantage in the ratio of five to one is shown for the incandescent lamp. A condition was assumed of two arc lamps placed 600 feet apart, as compared with lighting the same 600 feet with seven bunches of incandescent lamps of fifty candle-power to the bunch. This is not a correct comparison, because with the two arc lamps placed at the ends of the 600 feet, and seven bunches of incandescents placed over the same length of street, the comparison should have been made with one arc lamp instead of two. One arc lamp placed in the middle of the 600 feet would have given exactly the same maximum and minimum illumination within the 600 feet as given by the two lamps. On the basis of the incandescent lamps taking 3.1 watts per candle power, the seven bunches would have used 1,085 watts, or twenty per cent more than two arc lamps, or 240 per cent of the watts consumed by one arc lamp. There is therefore an error of 140 per cent in the comparison given.

One of the well-known gas men of the country at a recent gas convention read a paper on street lighting. In it he compared a city block of the usual length lighted with gas lamps with the same block lighted with arc lamps placed at each end of the block, and compared the cost of said lighting on the basis of the number of gas lamps in one block offsetting the cost of two arc lamps for said block. It is evident, however, that with arc lamps at street intersections there is only one arc lamp to the block, instead of two, and that he made an error in favor of gas lamps of 100 per cent. He also made the point, now being generally used in favor of Welsbach lights for street lighting, that by distributing a number of smaller candle power lamps over a given length of street you get a more uniform and more satisfactory illumination than with more intense arc lamps placed at greater distances apart. We must meet that argument and that condition with a lamp that gives a large horizontal illumination rather than a large mean spherical illumination. We want a lamp that will throw a practically horizontal ray, and we get that result in the alternating better than in any other style of lamp. Actual photometric curves from the 7.5-ampere inclosed alternating arc lamp, from the 6.6-ampere direct-current lamp, and from the 9.6-ampere open direct-current lamp, show that, putting all the lamps at the same height from the street, say twenty-five feet, at a certain distance from a point under the lamp the candle-power curve of the direct-current inclosed arc will cross the candle-power curve of the open arc. At a certain greater distance the alternating curve will also cross the curve of the direct-current open arc. At a still greater distance a 7.5-ampere inclosed alternating curve will actually cross the curve of the 6.6-ampere inclosed direct-current lamp. If this be true—and it is shown to be so by actual photometric tests carried out to a distance of 300 feet from the lamp—the alternating lamp is the best lamp for usual street lighting conditions.

The alternating lamp tends to throw a large amount of its light into the upper hemisphere, therefore you must consider the alternating lamp with a good reflector; and while without a reflector it might not compare favorably with the direct-current 6.6-ampere inclosed arc, we must compare it on the basis of the conditions under which it would actually operate. Using a reflector with the alternating lamp, we get the results spoken of.

In figuring on the saving that can be effected by using the inclosed lamps, the amount of saving depends largely on what has been our cost of trimming the open lamps. In figuring on a saving of $10 or $12 per lamp per year, it is evident that the cost of trimming the open arcs must have been somewhere near $12 to $15 per year. But I have known, of my own knowledge, that 9.6-ampere open arcs, burning on a 4,000-hour schedule, have been trimmed at less than $9 per year. Therefore, if you can trim the inclosed lamps at $1.28 it leaves a possible saving of less than $8 per year in the cost of trimming alone.

The question of the efficiency of the alternating system between the lamp and the switchboard, or, rather, between the lamp and the engine, is a question I do not care to discuss in detail now. There is, however, a very great saving there, which will represent a large saving in coal, in attendance, and in repairs in the station, in favor of the alternating arc as compared with any of the usual existing systems of arc lighting with separate arc-light machines. The saving in the station in favor of the alternating arc is so great that even accepting as a fact the most biased claims of superiority for the direct-current arc as to efficiency as compared with the alternating, the saving will counterbalance it and still leave a very large margin in the station in favor of the alternating arc.

MR. SMITH: In a station near to us, in Woburn, Massachusetts, they installed one of these systems a little less than two years ago, substituting it in place of the open-arc lamps. They were supplying the half arc in the city of Woburn and the full arc in the towns of Stoneham and Winchester. The lights were far apart, as in all country towns, and they substituted the 6.6-ampere alternating inclosed; and I am told by the manager of that plant—and I have no reason to doubt it; I have seen the lights myself—that all the people are much pleased with the change, and consider the 6.6 alternating lamp to give better service on these streets than even the full arc did on the other system. Of course, that would not apply where you have the full arcs placed near together; but at the distance apart that the lamps are placed there the inclosed arcs are giving better satisfaction than the half arc open or the full arc open. Professor Robb, as I understand, has eight transformers. I will ask him if they have any extra transformer in case of an accident to any one of the eight?

PROFESSOR ROBB: When we started in we always carried a spare transformer. We recently put in 100 lights and took the spare transformer for operating them. We never found any use for it, but it is good practice to keep a spare transformer; I would advise having one. To a great extent, it depends on how large the system is and how long you can wait for repairs. We do not think of being without an extra 2,400-volt static transformer. If the lightning gets into the transformer and destroys it, you will want one badly, and if you have to wait nine months to have the new one delivered to you, you will feel very sad. You would never run ten Brush machines without a spare one.

MR. SMITH: I have 500 arc lights, and have been advised both ways; to have a spare transformer and not to have one.

MR. HINE: I would ask, Professor Robb, whether you have had a dead short circuit on the alternating-current series arc line. If so, what happened? And if you never had one, what would happen if one should occur?

PROFESSOR ROBB: Mr. Rollins, our general manager, who is here, is more familiar than I am with what would happen in such a case, and I will ask Mr. Rollins to say if we have had a short circuit.

MR. ROLLINS: We have never had a short circuit. Part of the circuit has been cut out, but not entirely. The transformer regulates perfectly, and we have had no trouble.

PROFESSOR ROBB: We have had a short circuit experimentally, and have had no trouble. The current runs up, but we have had no trouble. The carrying capacity of the primary and secondary is sufficient to carry the increased current. My impression is that when secondary current is nominally 6.5 amperes on dead short circuit, the current runs up to 7.5 amperes, and in the same ratio on the primary.

MR. HINE: Does it damage the lamps?

PROFESSOR ROBB: No, sir.

MR. WAGONER: In regard to the question just raised: While the 100-light constant-current transformer is not designed to keep the current constant at 6.6 amperes down to short circuit, it will do so in many cases. The reason for this variation in operation is the fact that in this type of apparatus a small variation in assembling, such as varying the distance apart that the iron legs are placed, will make a sufficient difference in the regulation to cause the result mentioned. Most of these transformers regulate perfectly down to short circuit, although they will not all do so. In practically the worst cases, the current on short circuit will not rise above approximately seven amperes on a 6.6-ampere circuit. If the transformer is suddenly short-circuited when operating under full-load conditions, there is a slight increase of current momentarily until the coils can take the position for light-load operation. No damage to the transformer, line or lamps, however, would occur.

Mr. Wagner (St. Louis): I would call attention to the fact that in most of these comparisons between the alternating and the direct-current lamps in which the efficiency was mentioned at a certain number of watts per candle, the tests were made on 6.6-ampere alternating arcs. The 7.5-ampere alternating arc has a higher efficiency per watt of current consumed than the 6.6. This has been shown in a number of photometric tests, and is accounted for by the greater current density in the carbons and in the carbon points. This has long been known to increase the efficiency of direct-current arc lamps, those lamps having a large current in proportion to the number of watts consumed in the arc having a higher efficiency than those with the same number of watts with less current and higher voltage. All these comparisons would be still more favorable to the alternating arc if the comparison were made with the 7.5-ampere lamp. I think Professor Robb has made some experiments in that line, and has reached the same conclusion.

Professor Robb: As regards photometric tests of arc lamps, I think the main question before us is what the city authorities and what the public think of the lamps. There undoubtedly have been comparative tests made in cities as large as Boston, and in the smaller towns, and circuits of different kinds of lamps have been run in adjoining sections of the city and where the city authorities have had their choice between inclosed-arc lamps and open-arc lamps; and in the cases with which I am acquainted the city authorities have in every case chosen the inclosed-arc lamp. That proves to my mind that a central station is perfectly justified in adopting such a lamp. I do not think it means that we discard altogether the light that is near the lamp; but it does not mean that we give it the same value that we give the light remote from the lamp, and I do not think we should. I do not think any of us have ever seen an arc light operating satisfactorily that did not give enough light fifty feet from the lamp, whereas the mean spherical candle power of a direct-current inclosed arc will be greater than that of an alternating-current arc; still, the tests by Mr. Ryan, and which were published in the proceedings of the Electrical Engineers, show that at a distance of about sixty feet from the arc, provided the arc is twenty-five feet above the street, the alternating inclosed arc gives a greater candle power than the open-air direct-current arc, with the commercial lamps now on the market. These tests show in every case that with the same watts at a distance of between fifty and sixty feet, the candle power given by the alternating-current lamp inclosed was greater than that given by the direct-current lamp inclosed. Probably all of you have seen photographs taken of streets illuminated first with open-air arcs and then with inclosed arcs. While these photographs do not show up the photometric values of the lamps, owing to the fact that the rays that affect the eyes may not be the same as those that affect the photographic plate, they show the distribution of the light, and show that we have it more where we want it with the inclosed than with the open-air lamps.

MR. SCOVIL: I should like to ask what is the condition of the outer globes; whether you can afford to leave the lamp to run for six days without cleaning the outer globe. In a manufacturing city like Cleveland, we find that we can not leave the inclosed-arc lamp without cleaning for six days. The dust and dirt settles on it to such a degree that when there is a rain storm the outer globe is usually streaked in such a manner as to give the lamp a disreputable appearance, and we have to send a man to clean it off. I think a good many of us will have to take into consideration the fact that we shall have to send a man to clean the lamp oftener than once in six days. A good many of the comparisons that are being made as to the saving between various styles of lamps are based on comparisons between old lamps and new lamps, and of course in such cases the new inclosed lamp will have an undue advantage over the old open lamp.

PROFESSOR ROBB: You must take local conditions into account. I can see how in the clear atmosphere of New England you would not have to clean out the globes as often as in the city of Pittsburg. I have not had any experience bearing on the atmospheric conditions of Cleveland.

MR. NEAL: Professor Robb, you heard what Mr. White said in relation to the saving of expense at the central station where the alternating current was used in connection with the inclosed arc. Is there a corresponding saving of expense where the direct current is used in the central station?

PROFESSOR ROBB: There is a saving, but not so great; it depends on the system. If you are using a system where the dynamos are belted from the shaft, and you adopt instead of that a motor-driven system, the latter will require less attendance, but you still have the attendance on the arc machines. The same is true with the inclosed arc as with the open.

MR. NEAL: Under the same conditions?

PROFESSOR ROBB: I do not think there would be any difference between the two direct-current systems. I believe the cost of operation at the central station would be the same.

MR. WAIT: Mr. Wagner and Professor Robb both spoke of the higher efficiency of the lamps at 450 watts. I might state that in the curves referred to in the *American Electrician*, both with direct-current and the alternating-current lamp, tests were taken at 450 watts. I happen to have here some of the curves made by Mr. Ryan, to which Professor Robb refers, in which he states that the curve of the alternating lamp crosses that of the direct-current lamp at sixty feet. The alternating-current lamp curve crosses over the direct-current open lamp at about that distance, but does not cross over the inclosed direct-current lamp curve at all.

PROFESSOR ROBB: You probably have a different set of curves. Mr. Ryan has made experiments extending over two years, and we are probably talking at cross purposes.

THE PRESIDENT: The discussion on this subject seems to be about concluded.

THE PRESIDENT: I will appoint as a committee on nominations Mr. Samuel Insull, Chicago; Mr. Charles R. Huntley, Buffalo, and Mr. E. R. Weeks, Kansas City.

PROFESSOR GOLDSBOROUGH: Mr. President and gentlemen: I have a telegram from Washington bearing on the question of the need of a national bureau for standardization of electric lighting instruments and for other purposes. I have been asked by the secretary, in consultation with other members of the association, to draw up a resolution expressing the feeling of the National Electric Light Association regarding the matter of establishing in Washington a standard bureau of this character. I therefore take pleasure in reading the resolution that has been prepared:

The National Electric Light Association, representing in the capacity of its membership $300,000,000 invested in the development of electrical industries, in annual convention assembled, have

Resolved, That the National Electric Light Association, feeling the great necessity for the establishment of a laboratory that would be able impartially to furnish authoritative standards, earnestly recommends the passage by Congress of the bill providing for the establishment of a National Standardizing Bureau.

MR. BEAN: I move the adoption of the resolution.

The motion was carried.

PROFESSOR GOLDSBOROUGH: I would now move, Mr. President, that the secretary of the association be instructed to telegraph this resolution to Speaker David B. Henderson, of the House; to S. W. Stratton, Washington, D. C., and to Chairman Payne, of the Committee on Ways and Means.

The motion was carried.

THE PRESIDENT: We will now proceed to the consideration of the paper by Mr. Henry L. Doherty on "Equitable, Uniform and Competitive Rates."

MR. DOHERTY: Mr. President and Gentlemen: I tried to select for an example the average sized station represented in this association, and found it would figure out at a population of 100,000. I could not find a town of that size from which I could get any absolute data, so I then selected the second nearest available size of the average central station of the country, and, as Professor Jackson properly remarked yesterday, the average central station is very small. The central station you see outlined here is in a city of 18,000. That represents a larger central station than the average; but I have purposely taken a small central station, because the conditions in the large central stations are influenced greatly by local matters.

Mr. Doherty then read the following paper:

EQUITABLE, UNIFORM AND COMPETITIVE RATES

We probably all agree that the rate question is of vital importance to the development of central-station work. Of the several methods proposed, none are universally satisfactory, even to the managers of stations similarly situated, and many of us are not satisfied with any of them.

The natural laws governing the sale and purchase of electric current do not differ greatly from those of any other commercial business, except in one particular; the average commercial business is at liberty to bargain and sell with each consumer; it is at liberty to discriminate in prices or methods.

Any company enjoying public grants is apt to be considered as a quasi public corporation, and is amenable to the general laws of this class. Frequent suits have been brought to determine the right of a quasi public corporation to discriminate in rates between various customers, and in almost every instance the court has held that such discrimination was illegal. Numerous decisions would warrant us in considering the illegality of discrimination to be an established fact. The whole question, then, must hinge on what constitutes discrimination. There is probably more legislation in vogue for the control of railroads than for any other class of quasi public corporations, and the Interstate Commerce Commission (a national board of control) permits them to charge different rates per ton for different distances, not proportional to the distance, and also permits them to charge different rates per ton for the same distance for different commodities. This would warrant the belief that we could legally discriminate in our methods of charging between different classes of service and different classes of consumers.

The right to bargain with each customer is a doubtful advantage, and private business houses that are not amenable to legal prevention against discrimination have nearly all abandoned this policy in favor of a similar policy that is forced upon us legally. In view of the fact that they deal with the same class of people as the customers of the average central station, it is natural to suppose that our eventual policy will be one price to all, regardless of legal coercion.

The electric business was started as a competitor to gas. The early promoters of this new method of lighting were naturally inclined to adopt the same methods of charging as then in vogue among their competitors. Without meters, they were compelled to use flat rates. Later, when meters were procurable, they adopted the system used by the gas companies, and have since gradually awakened to the fact that while this system may be suitable to gas business (which is questionable), it is not suitable to the electric business. Much of the experience gained in the gas business is applicable to the electric business, but there are certain distinctive features for which compensation must be allowed. Gas companies can manufacture uniformly for twenty-four hours, being able to store their product cheaply and economically. The distribution of gas does not require any exact degree of pressure regulation. The conductors used are hollow, and the cost does not increase proportionally to the increased conductivity.

I give below some comparative figures, which I think forcibly indicate some of the differences between the electric and gas business, requiring special consideration :

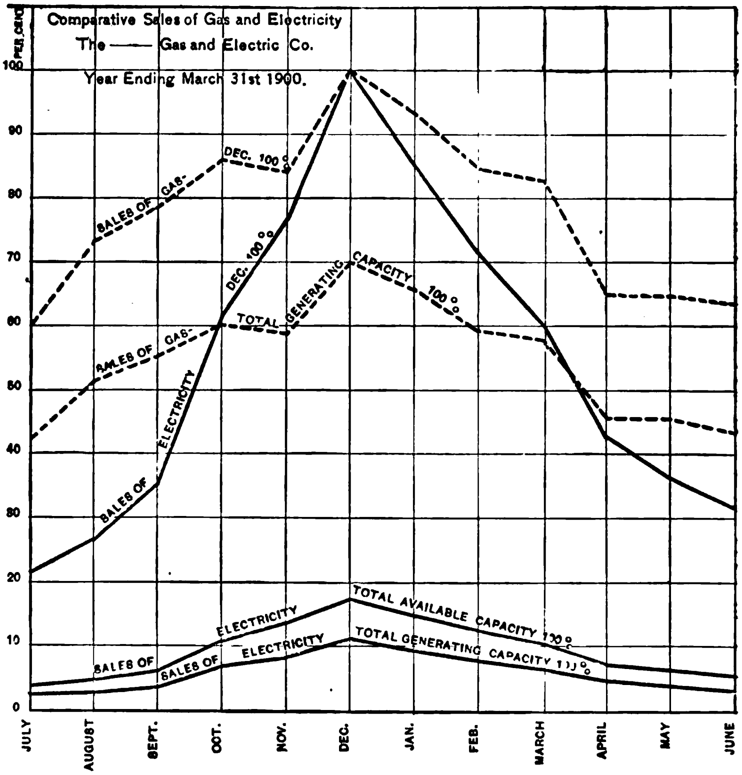
COST OF STORAGE CAPACITY

Gas per 1,000 cu. ft.....	$50.00	
Gas per ft....	.05	
Electric per K. W.-hour	100.00	
Gas per C.-P.-hour.....	.0033⅓	Incandescent gas lamp, 15 candles per ft.
Electric per C.-P.-hour.	.10	Arc lighting, 1 Watt per candle.
Gas per C.-P.-hour....	.0166	Open flame, 3 candles per ft.
Electric per C.-P.-hour.	.312	Incandescent, 3.1 Watts per candle.
Gas per K. W.-hour, developed.	1.25	Gas engine, 25 cu. ft. per K.W.-hour.
Electric per K. W.-hour, developed...........	125.00	Electric motor, 80 per cent efficiency.
Gas per $1.00 unit of value................	50.00	$1.00 per 1,000 cubic ft.
Electric per $1.00 unit of value............	1,000.00	.10 per K. W.-hour.
Gas per million B. T. U.	76.97	650 B. T. U. per ft.
Electric per million B. T. U...	29,312.53	778 ft.-lbs. per B. T. U. 3,411.51 B. T. U. per K. W.-hour.
Gas – Efficiency (approximately)	100 per cent.	
Electric—Efficiency (approximately)........	56 to 72 per cent.	

CONDUCTORS

Gas—Size of pipe (cast-iron)......	2 in.	4 in.	8 in.	16 in.	30 in.	60 in.
Area—in circular inches....	4	16	64	256	900	3,600
Conductivity..	1	5.65	32	180	880	4,950
Relative conductivity per circular inch.............	1	1.4	2	2.75	3.9	5.5
Relative conductivity of electric conductors.	1	1	1	1	1	1
Weight of pipe per foot.....	6	17	40	100	250	900
Relative conductivity per pound..................	1	2	4.8	10.4	21.2	33.5
Relative conductivity of electric conductors...........	1	1	1	1	1	1

I also give daily and yearly load curve for the same city for gas and electric service, showing also the percentage "sendout" compared with the generating capacity of the two plants:



The central-station business is one composed largely of fixed charges, whose aggregate amount is not appreciably affected by the quantity of current sold. The cost of current delivered on the consumers' premises is more greatly influenced by a high kilowatt consumption compared with the maximum demanded than by any other factor affecting our cost.

Tiresome as it may seem, I shall have to consider the better known systems of charging before proceeding further with my argument. I shall confine this discussion to the several distinctive methods of charging now in vogue, and shall not attempt to discuss the numerous variations that have been injected into them to compensate for their lack of ability to meet the objections of the managers adopting them.

The main distinctive systems are as follows:

First—Flat rates.

Second—Uniform meter rates.

Third—Meter rates differing on quantity of consumption.

Fourth—Meter rates with a minimum guarantee.

Fifth—Meter rates different on amount of time maximum capacity of installation is used.

Example: New York system.

Sixth—Meter rates varied by the amount of time maximum demand is used.

Example: Wright demand system.

Seventh—Meter rates varying according to time of day at which current is used.

Example: General Electric Company two-rate meter.

The first four of these systems do not, I think, have a single prominent advocate. The New York system is only mildly advocated by the users, and they admit that it is inequitable. The two latter systems are advocated by some of the most prominent men in the profession, but their most sincere advocates are those interested in the patents on the appliances which their use demands. I say this without any wish to cast reflection upon the advocates of these systems. If any of us think a thing is good enough to buy, we should certainly think it good enough to advocate, and we should be entirely justified in doing so; but when we, as central station men, consider any of the problems in our business, we naturally feel that a financial interest in any one system is apt to warp the judgment of the one so interested.

FLAT RATES

Objections

First—They are not suited to all classes of consumers.

Example A—The long-hour consumer pays less than cost.

Example B—The short hour consumer cannot patronize a station of this method of charging, as the cost is apt to exceed that of other means of lighting.

Example C—The cost to the consumer with a big installation and a small maximum demand is prohibitive.

Second—Rigid inspection is required.

Example A—Fraud is possible by increasing the number of lights, by increasing wattage of the lamps used, and by the theft of current for other uses.

Third—The installation is curtailed.

Arguments in Favor

First—If the rate is high enough, no loss can occur to the station except by fraud.

Second—The system permits of simple office records, and offers little opportunity for disputes between company and consumer.

Third—The income is constant, and can be safely anticipated.

Fourth—The fixed charges of the plant are insured.

Fifth—They require no investment for meters.

Sixth—They permit of accurate calculations of the distributing system.

Seventh—Their legality is not apt to be questioned.

UNIFORM METER RATES

Objections

First—They are not suited to all consumers.

Example A—The short-hour consumer very probably does not pay the cost he occasions.

Example B—The long-hour consumer can often procure other service more cheaply.

Second—The rapidity with which bills increase in the fall gives rise to dissatisfaction among consumers, which is a menace to the safety of central-station investments.

Third—They are the greatest encouragement to the installation of isolated plants, owing to the fact that the long-hour consumer can manufacture his own current the most cheaply, and it is from this class of consumers that the maximum profit is demanded by this system.

Fourth—As the central station must carry some consumers at a loss, they cannot sell to profitable consumers at a price permitting competition with isolated plants and other means of obtaining light.

Fifth—They encourage heavy peaks and discourage liberal use of current for lighting and other purposes.

Sixth—They require constant arbitrary adjustment of rates.

The second reason given is, I think, of more importance than is generally recognized.

I append chart, showing the number of burning hours in each month in the year, and a careful study of this tabulation shows a remarkable increase in light bills in approaching the season of least natural light:

TABLE SHOWING NUMBER OF HOURS ARTIFICIAL LIGHT IS NEEDED IN EACH MONTH OF THE YEAR

Evening from	July	August	September	October	November	December	January	February	March	April	May	June	Total
Dusk to 6 o'clock	...	...	2	33	62	80	65	33	4	...	...	...	279
Dusk to 7 o'clock	...	14	22	62	92	111	96	61	31	4	...	...	493
Dusk to 8 o'clock	...	40	52	93	122	142	127	89	62	28	4	...	759
Dusk to 9 o'clock	13	71	82	124	152	173	158	117	93	58	29	8	1,078
Dusk to 10 o'clock	44	102	112	155	182	204	189	145	124	88	60	38	1,443
Dusk to 11 o'clock	75	133	142	186	212	235	220	173	155	118	91	68	1,808
Dusk to 12 o'clock	116	164	172	217	242	266	251	201	186	148	122	98	2,183
All night	217	307	345	421	473	527	512	411	382	295	242	195	4,327
Morning from													
4 o'clock to dawn	...	16	48	80	110	137	137	93	71	28	2	...	722
5 o'clock to dawn	...	...	18	49	80	106	106	70	40	3	...	...	472
6 o'clock to dawn	...	...	...	18	50	75	75	42	9	...	...	...	269
7 o'clock to dawn	...	...	...	...	20	44	44	14	...	...	...	...	122

Arguments in Favor

First—Next to flat rates they require the least investment for measuring apparatus, and a more simple system of office records than the two-rate system.

Second—Less attention is required than for any of the two-rate systems.

Third—The legality of this system is not apt to be questioned.

METER RATES BASED ON QUANTITY OF CONSUMPTION

Objections

First—They do not properly discriminate between customers of unequal worth.

Second—A lesser consumption often costs more than a slightly greater consumption.

Third—Their legality is questionable.

Fourth—In addition to these objections, they have all the objections of the uniform meter rate system, except perhaps in a slighter degree.

Fifth—They are generally based on nothing accurate, and represent only the whim of the maker.

Arguments in Favor

First—They require less frequent arbitrary reductions in rate than the uniform meter rate system.

Second—Less attention is required than for any of the two-rate systems.

METER RATES WITH A MINIMUM CHARGE

Objections

First—The minimum charge is generally based on illegal grounds, and does not represent minimum cost to station for "readiness to serve."

Second—They do not properly discriminate between consumers of unequal worth.

Arguments in Favor

First—The company is partially or wholly insured against loss on short-hour consumers.

Second—Insurance against loss permits them to sell to their profitable consumers at a more equitable rate.

METER RATES BASED ON QUANTITY OF TIME MAXIMUM CAPACITY OF INSTALLATION IS USED

This is what I term the New York system, and is one where the consumer pays at a high rate for the first one, two or three hours' use of his total capacity, all additional current being given him at a much lower rate.

Objections

First—They are not suited to all classes of consumers.

Example A—The short-hour consumer pays less than the cost of service.

Example B—They unjustly discriminate against the consumer with a large installation and a small demand.

Example C—The short-hour consumers pay the same rate per kilowatt until they reach a certain consumption, and yet it is axiomatic that the consumer that uses current for nearly all of the required time is much more valuable than the consumer that uses current for only a small portion of the time.

Second—Frequent and rigid inspection is required.

Third—Fraud is encouraged.

Fourth—A liberal installation is discouraged.

Fifth—The necessity for arbitrary reductions in rates is not entirely eliminated.

Sixth—The legality is questionable.

Arguments in Favor

First—They encourage longer-hour consumption of the long-hour consumers.

Second—They require a less investment for measuring apparatus than any other two-rate system.

Third—Less attention is required than for the two-rate or Wright demand system.

METER RATES VARIED BY TOTAL TIME MAXIMUM DEMAND IS USED

Or what is generally known as Wright demand system.

Objections

First—It is not suited to all classes of consumers.

Example A—Short-hour consumers do not pay full cost of service.

Example B—Long-hour consumers must be made to pay more than cost of service and proportional amount of profit to compensate for loss on short-hour consumers.

Second—A liberal installation is apt to be discouraged.

Third—Liberal consumption is also apt to be discouraged for the sake of keeping down maximum demand.

Fourth—Consumption is curtailed to lower demand registrations at seasons when peak is not undesirable.

Fifth—This system is apt to occasion the greatest possible fluctuation of peaks for different months in the year, while a uniform peak is desirable.

Sixth—The charge bears no exact relationship to the cost.

Seventh—Errors in reading cannot be rectified.

Eighth—Accuracy of readings cannot be demonstrated.

Ninth—The equipment is expensive.

Tenth—It is the most complicated of all two-rate systems and is the least apt to be fully understood by the consumer, and, therefore, not apt to inspire the consumer with confidence.

Eleventh—Cost of inspection is increased.

Twelfth—It is possible for the company to be defrauded by collusion between the inspector and the consumer.

Thirteenth—It does not eliminate the necessity for arbitrary reduction in rates.

Fourteenth—Its legality is questionable.

Arguments in Favor

First—In general the charge to the consumer more closely approaches the cost he occasions than any of the other systems enumerated.

Second—It permits concessions to valuable consumers with some degree of accuracy.

METER RATES VARYING ACCORDING TO TIME OF DAY AT WHICH CURRENT IS USED

Example—General Electric Company's two-rate meter.

Objections

First—It is not suited to all consumers.

Example A—A short-hour consumer does not pay as much as the service costs.

Example B—It discourages the use of light at a time when such use is desirable.

Second—It is apt to inspire but little confidence in the consumer.

Third—It is expensive to buy and to maintain.

Fourth—It charges the most for current at a time when the cost is least.

Fifth—It does not properly discriminate between short-hour and long-hour consumption.

Sixth—It requires frequent settings for different periods of the year.

Seventh—Its legality is questionable.

Arguments in Favor

First—It encourages consumption at some of the desirable hours.

Second—Errors in reading can be rectified and their accuracy demonstrated to the consumer.

None of these systems will show any exact relationship between the cost to the central station and the charge to the consumer. Charging on basis of maximum capacity installed is so inequitable, that I hardly feel called upon to defend my objections to it.

The Wright demand system has certainly proved a step in the right direction, but the fact that of even its warmest advocates no two agree exactly as to how it should be used, seems almost conclusive evidence that it is not by any means perfect.

The two-rate meter is also an important change from former methods, but it is almost ridiculous to sell current at a lesser price when it costs us most and at a greater price when it costs us least. Assuming that commercial expediency warrants this peculiar condition, there are other and more serious objections which limit its use to special cases.

During the past two years I have made a careful physical and financial examination of twelve stations, in cities varying in size from 12,000 to 250,000 population; during the same period I have made a similar but less thorough examination of eight central stations, in cities varying in size from 4,000 to 600,000. In every case it seemed to me that a good system of rates was more badly needed than anything else. None of the stations had uniform rates; four of them had more than fifty per cent of their consumers on special rates. None of the systems outlined above were universally applicable to all the central stations examined.

Paradoxical as it may seem, the stations realizing the lowest income per kilowatt-hour were generally making the largest return on their total investment. As all of these stations showed the greatest kilowatt output compared with their total generating capacity, I have concluded that their increased earnings were entirely due to a greater use of light, which is very apt to follow the introduction of low rates.

In addition to the examination of other stations, I have had occasion to fix rates for three central stations during the past year. Of the many trying problems that are apt to confront a central-station manager, I am free to confess that I felt less ability to deal with the rate question than with any other that might have come up. I have tried to study the rate question, simply to be able to act intelligently when again forced to decide on the rearrangement of rates for an existing central station or on the arrangement of rates for a new central station.

From a commercial standpoint, we are governed by two general laws:

First—We must not sell at less than cost to us.

Second—We must sell at no greater cost to the consumer than that at which the same service or a suitable substitute can be obtained by other means.

This gives us certain limitations upon which to base our methods of charging.

First—Our minimum must be not less than the cost to us; and
Second—Our maximum must be not greater than the worth to the consumer.

Other factors that may be considered are these:

First—If we must provide for a heavy peak for one month or one night in the year, it is desirable to have as nearly as possible the same demand throughout the year (assuming, of course, the same characteristic load curve), and any system tending to depress this peak at other seasons than our maximum load, is unwise and objectionable.

Second—Any system that tends to depress this curve at any other point than the peak, is unwise and objectionable.

Third—If we lose on one customer, we must make it up on another customer.

Fourth—If we lose on some customers, we cannot sell so cheaply to others, and are at a disadvantage when sharp competition is met.

Fifth—If we lose on one consumer for a portion of a year, we cannot realize the same yearly profit without charging a correspondingly higher profit for the rest of the year.

Sixth—There are certain short-hour consumers that are a loss to the central stations' operation at even twenty cents per kilowatt-hour.

Seventh—The variations in cost of lighting to the consumer during different seasons of the year should not be greater than the variations in cost to us.

Eighth—Legal restrictions in central-station operations will increase rather than diminish.

Ninth—It is desirable that our methods of charging should permit of favorable comparison with other means of illumination, and especially with isolated plants.

Tenth—Under an ordinary meter-rate system a consumer that has two means of illumination is apt to use electricity for short-hour consumption and other means for long-hour consumption.

Eleventh—We are more interested in knowing what our consumers' maximum demand is going to be, than in knowing what it has been.

As one of the chief factors in determining the proper methods of charging is to meet competition, a short consideration of this subject is not out of place. It is probably necessary to consider only the sources of competition named below.

I give the first three of them in the order that I consider to be their future importance:

First—Natural light.
Second—Isolated plants.
Third—Mineral oil.
Fourth—Gas.

I do not attempt to place gas in any order of importance, as its future for lighting is largely problematic, and should I give the possibilities that I see for this agent, it might lead the discussion from the real merits of the subject of my paper. I will consider it only in the sense of its present development.

The competition from natural light is seldom considered, in spite of the fact that in many instances artificial light is cheaper and more satisfactory than natural light. The most frantic efforts in architecture are often made to obtain natural light and ventilation, frequently at the sacrifice of room and economy in building. I believe many of our modern buildings could be artificially lighted and ventilated at less cost than the sacrifice of room often requires. Natural light is not always to be preferred to artificial light. I have often closed my shade while in my office in New York, and have resorted to artificial light in preference to the reflected light from the glazed wall on the opposite side of the court, which is at times extremely irregular, owing to the sun being momentarily obscured by clouds.

The primary reason for architecture that yields artificial light is often an effort for ventilation, which can always be more satisfactorily furnished by artificial means. The manager of a large industrial plant told me that to his surprise the cost of production had been materially lessened by working the factory double time. The cost of artificial light had proved to be considerably less than expected and very much less than other savings effected.

Isolated plants have proved active competitors and a thorn in the flesh for more reasons than one. Of all forms of competition I like this one least. Bad methods of charging have cultivated the isolated plant to an appalling extent. Inability accurately to determine cost of service, backed by threats of isolated plants from consumers, has cost the central stations of the country thousands of dollars. An isolated plant generally robs the station, not only of a large consumer, but of a long-hour customer, and hence a profitable one.

In reported costs of current from isolated plants, nothing is ever allowed for interest, depreciation and ground rent, and seldom is anything allowed for repairs, risk and wages. The installation of isolated plants can generally be forestalled, but competition from oil and gas cannot be entirely eliminated. Many buildings have boilers already installed for heating, and they feel that the cost of operating a dynamo will not be much greater. They sometimes forget that heat is wanted but a few months in the year, and is objectionable for the rest of the year; that in the heating season heat is wanted most in the morning when no light is wanted, and least in the evening when most light is wanted.

Competition from isolated plants requires the central stations' most careful consideration. The installation of one isolated plant is apt to encourage the installation of others, and isolated plants often grow into competing central stations, and in making new plans for methods of charging we should consider competition from isolated plants more than from gas and oil.

There are certain classes of short-hour consumers that the central station cannot possibly hope to supply at a profit. If supplied at a loss, other customers must pay this.

Aggressive competition with gas is apt only to precipitate an active war which will be harmful to both companies. Those who use electricity under ordinary methods of charging and also use oil or gas, generally use the electricity for intermittent and short-hour use and the other means for constant and long-hour use.

A method of charging which will reverse this order is what is wanted. Better let the gas company supply the consumer you cannot supply profitably, and aim to get in return a long-hour consumer that you can supply profitably.

Acetylene gas has been given no attention, although it may demand careful consideration later. It was demonstrated six years ago that acetylene could be marketed at a competitive price with gas and electricity, but up to date there seems to have been more attention paid to the marketing of the stock and bonds than to the commodity.

The details of any satisfactory rate system must

First—Prevent fraud.

Second—Not unnecessarily complicate office records.

Third—Be easily understood by the consumer.

Fourth—Be competent without objectionable inspections, which reflect on the honesty of the consumer.

Fifth—Encourage a liberal use of current compared with maximum demand.

Sixth—Inspire the confidence of the consumer in its accuracy.

If it calls for any special measuring or recording instruments they must meet the following conditions:

First—They must be inexpensive to purchase and install.

Second—They must be durable and reliable.

Third—They must require minimum attention.

Fourth—Chances for errors should be as little as possible, and errors in their action or reading should be capable of correction, with ability to demonstrate this to the consumer.

Owing to lack of time, I have read comparatively little of the literature on the rate question. To avoid repetition, which unnecessarily consumes the time of a convention like this, it is highly important that all published literature on any particular subject should be thoroughly read before attempting to add to it. I have been the victim of circumstances in gathering data on which to base my arguments. I intended to take the average results of many plants to determine cost of installation and operating expenses, but the reports showed such a marked variation that they could not be intelligently used without further investigation. I obtained practically no information that could be intelligently used in a paper of this sort. I did, however, obtain much information that proved interesting to me, and information that I think will also interest others. In general, the cost of the plants appeared to range between $200 and $400 per kilowatt capacity, sometimes going to $1,000 per kilowatt capacity. The percentage demand per connected load seemed to vary from twenty-eight per cent to eighty per cent. A fair estimate would seem to be about thirty-five per cent on meter basis and seventy-five per cent on flat-rate basis. Consumption per lamp per year seemed to be very largely influenced by local conditions and the cost of current. It is reasonable to suppose that the average consumer increases or curtails his consumption more from a financial standpoint than from a standard of light. He fixes his mind on the sum he is willing to pay, and if his bills exceed this amount, he decreases his consumption.

Of the central stations reporting the higher the cost of current the shorter the use of the connected load, reports varied from 10,646 watts per year per lamp wired up to a figure incredibly high as compared with plants that have come under my immediate supervision. From eighteen to twenty-five kilowatt-hours per year per lamp wired up can be taken as a fair average for western cities. Compared with population, lamps wired up varied from one and one-half lamps per capita to one-fifth of one lamp per capita. Income per capita varied from fifty cents to $3.50 per capita. Income compared with investment varied from ten per cent to forty per cent. Difference between station output and current sold was seldom attainable, and plants reporting on this point generally showed losses that would cause a gas manager to have violent spasms. One alternating-current station reports an all-year efficiency of lines, meters and transformers of over seventy per cent, and a monthly efficiency for December and January of over eighty per cent. Only one station separates difference between station meter registration and consumers' registration into "accountable" and "unaccountable loss." From the gross difference they subtract transformer iron loss and meter shunt loss, and the difference is termed by them "unaccounted for," and is represented by their C^2R loss, faulty registration of meters, theft of current, and general sources of "unaccounted for."

In the reported costs of operation, some other interesting figures were noted. In general, the extreme variations could only be explained by different methods of accounting. Abundant evidence was to be had that the central-station business of the country is seriously in need of good and uniform accounting. In every instance the cost for boiler fuel was such a small portion of total expense as to lead me to believe that we have heretofore given this expense undue consideration. Cost of lamp renewals in different stations varied as much as the lengths of different pieces of string. Some stations reported cost of lamp renewals at almost a negligible figure. Two stations reported cost of lamp renewals at approximately the cost of boiler fuel. Assuming cost of lamps at eighteen cents each and a life of 600 hours, the expense is six-tenths of a cent per kilowatt-hour. This would be equivalent to cost of boiler fuel if six pounds of coal costing two dollars per ton were used per kilowatt-hour generated. The importance of this item of expense seldom seemed to appeal to the central-station manager, as the cost where shown on a kilowatt basis was generally figured on total output of station, which included current sold for power and arc lighting. One station has a much larger output in kilowatt-hours for power purposes than for incandescent lighting, and yet has but one-fourth of the generating capacity, both being taxed at their peak to the utmost.

The basic reason for meter rates based on quantity of consumption is the mistaken idea that the larger the consumption, the less the cost to the station. The basic reason for the New York and Wright demand system is the idea that the larger the consumption, the less is the corresponding cost to serve.

A certain expense is incurred for "readiness to serve" and an increased consumption does not occasion a corresponding increase in expenses. Now, if our cost is on this basis, and we want a system of charging that will correspond to the cost, why should we not make our rates on this same basis? Why should we not charge them at least our cost for readiness to serve?

Our expenses for "readiness to serve" are fixed by:

First—The number of consumers.
Second—The number of meters.
Third—The maximum current demanded.

If our cost is the result of these factors, why should we not base our charges on them? This seems to me the most natural and logical course. It corresponds to the cost for service from isolated plants, for such an installation occasions:

First—A certain cost for each plant, regardless of size.
Second—An additional cost, based on capacity demanded.
Third—An additional cost per kilowatt-hour generated.

If we are going to make a consumer pay for readiness to serve his maximum demand, how shall it be fixed or determined? Should a consumer pay for his maximum capacity or his maximum demand? If he is made to pay for his maximum capacity it will tend to curtail his installation, and thus probably lessen his consumption, and it also puts a premium on fraud, demanding expensive and objectionable inspections. Shall we take his maximum demand for the year or for the month? The central station must provide for his maximum yearly demand, and it seems to me conclusive that it is his maximum yearly demand he should pay for. Shall we make him pay for what he has demanded or for what he will demand? If we assume that a central station has but one consumer, and he provides an installation which will translate 400 kilowatts, we can hardly afford to let him pay for what he has demanded, but must make him pay the fixed charges for what he may demand, as this is what we have been compelled to provide. If we make him pay for only what he has demanded, and this is not equal to what he may demand, we must charge him a correspondingly higher rate for current, and this charge cannot be intelligently fixed in advance. I propose that we charge consumers at our cost for readiness to serve, allowing them to contract for whatever capacity they choose, limiting the capacity by suitable means; each contract to run a year and consumer allowed to increase his capacity at will, but not lessen it, except at the end of a year.

The following means have occurred to me for limiting his demand.

First—Fusing to capacity demanded.

Second—The use of a circuit-breaker in place of the fuse.

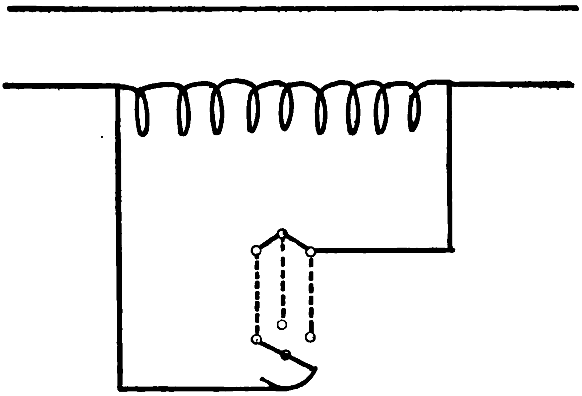
Third—An interrupter causing the lights to wink when capacity paid for is exceeded.

Fusing, to be satisfactory, should provide for a number of relay fuses connected on a multi-point switch, permitting the customer to throw on another fuse in case he should unconsciously exceed his capacity. An automatic electric bell or vibrator could be used to notify him that he is burning in excess of his capacity. If desired, a device as diagramed below could be used on alternating currents.

A circuit-breaker can be used in place of the fuse if desired.

For direct current, a resistance can be used in place of the reactance coil. An interrupter can be used on alternating currents, with movable coil or movable core, which will vary the electromotive force if the maximum demanded is exceeded. Numerous simple and satisfactory appliances can be provided to prevent the maximum demand being exceeded.

I would fix the charge for readiness to serve by the minimum cost to the station of all fixed charges and fixed expenses. I would proportion it on the



basis of: (*a*) consumer, (*b*) meters, (*c*) maximum demanded.

I give below an analysis of the results in one station for year ending May 1, 1900. The total expenses are in first column; division of fixed and operating expenses in columns 2 and 3; a percentage division of fixed charges in columns 4, 5 and 6, and their corresponding values in columns 7, 8 and 9. Taxes, interest and depreciation are obtained by estimates. The station has grown on the instalment plan, and the investment cannot be accurately determined. I have, therefore, estimated worth of station as follows to obtain my fixed charges:

Real estate	$5,000 @	5% app.	$250 00
Building	6,000 @	5% dep.	300 00
Boilers, heaters and pumps	12,000 @	8%	960 00
Engines and condensers	15,000 @	8%	1,200 00
Generators	12,000 @	8%	960 00
Switchboard	3,000 @	10%	300 00
800 poles set cross-armed	12,000 @	15%	1,800 00
60,000 pounds wire @ 18¢	10,800 @	2½%	260 00
Stringing wire	3,000		
Transformers	7,500 @	8%	600 00
1,000 service connections @ $5	5,000 @	10%	500 00
Lightning arresters and incidentals	3,000 @	10%	300 00
Engineering and supervising	6,000		
Legal expenses and rights	3,000		
Interest while building	6,000		
925 meters, $15	13,875 @	10%	1,387 50
18,000 lamps, 17¢	3,060		
	$126,230	6.62%	$8,317 50
Taxes @ 2% of 50%			1,262 30
Interest			6,311 50
			$15,891 30

Income and Sales

$38,480.18. 307,389 K.W.-hours sold. Average price, $0.12518.

Connected up,

900 consumers.	925 meters.	18,000 lamps.

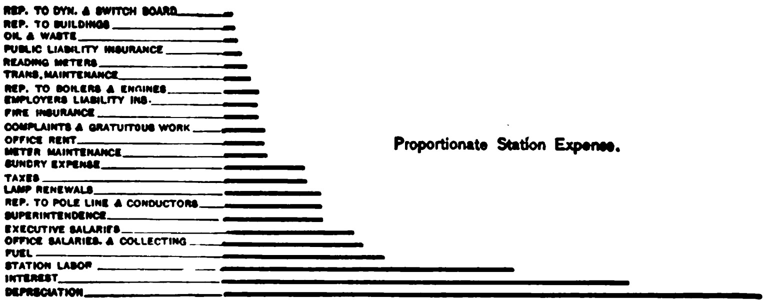
Consumption,

341.4 K.W. per consumer.	332.1 per meter.	17.06 per lamp.

I have assumed that the aggregate connections would equal two-thirds of the lamps wired up.

As a matter of interest, I give a graphic chart showing the corresponding value of these various expense items.

This system of charging will be immediately put in use at one central station with which I am connected, but the conditions are so unusual that you would not be particularly interested in the plans adopted. I am also seriously considering the advisability of putting this system in use in another station with which I am connected. I am afraid a charge of practically ten dollars per consumer will prove excessive, and have therefore fixed on an arbitrary charge of three dollars per consumer, and have raised my demand charge from $1.34 per lamp to $1.50 per lamp. I give you below a table showing the cost per lamp for various sized installations, based on charge for readiness to serve of three dollars per consumer per year; three dollars per meter per year; $1.50 per lamp demanded per year; and five cents per kilowatt for current, on basis of consumption of previous year, being 25.583 kilowatt consumption per lamp of estimated capacity demanded:


Proportionate Station Expense.

	Total expense	Expenses proportional to K. W. output	Minimum expense for readiness to serve	Percentage division			Value		
				Per consumer	Per meter	Per K. W. capacity	Per consumer	Per meter	Per K. W. capacity
				Per cent	Per cent	Per cent			
1. Fuel	$2478.00	$2478.00	....	....	....	....	....	....	....
2. Oil and waste	176.00	88.00	$88.00	....	....	100	....	....	$88.00
3. Repairs— Boilers and engines	493.00	393.00	100.00	....	....	100	....	....	100.00
4. Repairs— Dynamos and switchboard	88.00	88.00	....	....	....	....	....	....	....
5. Repairs— Buildings and property	132.00	32.00	100.00	50	....	50	$50.00	....	50.00
6. Station labor	4518.00	1338.00	3180.00	50	....	50	1590.00	....	1590.00
7. Repairs— Pole lines and conductors	1500.00	500.00	1000.00	50	....	50	500.00	....	500.00
8. Transformer maintenance	400.00	200.00	200.00	....	....	100	....	....	200.00
9. Meter maintenance	640.00	400.00	240.00	....	100	....	....	$240.00	....
10. Reading meters	336.00	....	336.00	....	100	....	....	336.00	....
11. Lamp repairs and renewals	1500.00	1500.00	....	....	....	....	....	....	....
12. Complaints and gratuitous work	600.00	600.00	....	....	....	....	....	....	....
13. Office salaries and collecting	2150.00	650.00	1500.00	50	....	50	750.00	....	750.00
14. Office rent	600.00	....	600.00	50	....	50	300.00	....	300.00
15. Stationery, postage and sundry expenses	1200.00	600.00	600.00	50	....	50	300.00	....	300.00
16. Fire insurance	500.00	....	500.00	50	....	50	250.00	....	250.00
17. Employees' liability insurance	500.00	250.00	250.00	50	....	50	125.00	....	125.00
18. Public liability insurance	250.00	....	250.00	50	....	50	125.00	....	125 00
19. Superintendence	1500.00	500.00	1000.00	50	....	50	500.00	....	500.00
20. Executive salaries	2000.00	....	2000.00	50	....	50	1000.00	....	1000.00
21. Taxes	1262.27	....	1262.27	25	*	75	280.88	138.75	842.64
22. Interest	6313.99	....	6313.99	25	*	75	1405 06	693.75	4215.18
23. Depreciation	8317.50	....	8317.50	25	*	75	1732.50	1387.50	5197.50
24. Profit	1025.42	1025.42	....	....	....	....	....	....	....
	$38480.18	$10642.42	$27837.76				$8908.44	$2796.00	$16133.32

Expense per consumer	$9.898
Expense per meter	3.022
Expense per lamp wired up	0.8963
Expense per lamp demanded on station	2.0166
Expense per lamp demanded by consumers	1.3444
Expense per K. W.-hour sold	0.03475

Meters installed	Lamps demanded, being two-thirds capacity installed	Yearly fixed charge	Yearly fixed charge per lamp demanded	Monthly fixed charge per lamp demanded	Yearly charge per lamp demanded, including current at five cents per K. W.-hour	Average monthly charge per lamp demanded, including current at five cents per K. W.-hour
1	1	$7.50	7.50	.625	8.78	.731
1	2	9.00	4.50	.375	5.78	.461
1	3	10.50	3.50	.291	4.78	.398
1	4	12.00	3.00	.25	4.28	.356
1	5	13.50	2.70	.225	3.98	.331
1	6	15.00	2.50	.208	3.78	.315
1	7	16.50	2.357	.196	3.636	.303
1	8	18.00	2.25	.187	3.53	.296
1	9	19.50	2.155	.179	3.435	.286
1	10	21.00	2.10	.183	3.38	.281
1	12	24.00	2.00	.166	3.28	.273
1	15	28.50	1.90	.158	3.18	.265
1	20	36.00	1.80	.15	3.08	.256
1	30	51.00	1.70	.141	2.98	.248
1	40	66.00	1.65	.137	2.93	.244
1	50	81.00	1.62	.135	2.90	.241
1	60	96.00	1.60	.133	2.88	.240
1	70	111.00	1.585	.132	2.864	.238
1	80	126.00	1.575	.131	2.854	.238
1	90	141.00	1.566	.130	2.845	.237
1	100	156.00	1.56	.130	2.84	.237

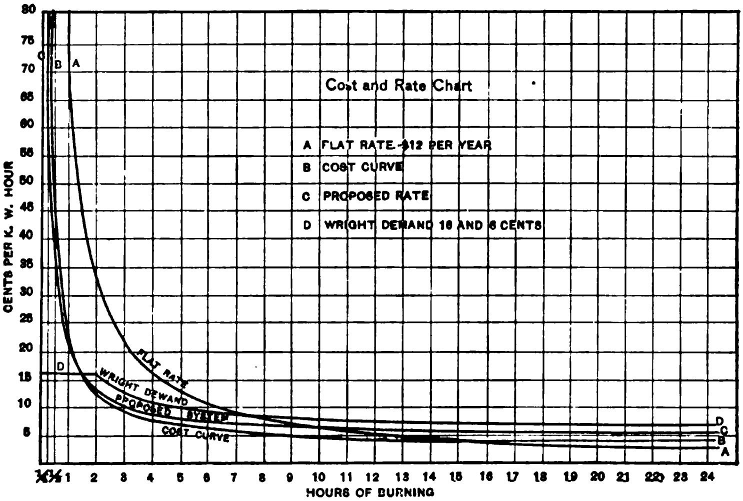
I give below a table showing cost per kilowatt for various yearly load factors from a quarter of an

Hours per day of using demand of station	K. W. output per year	Fixed expense per K. W.-hour output	Total cost per K. W.-hour output including operating expense	Receipts per K. W.-hour by proposed rate. $3.00 per service, $3.00 per meter, $1.50 per lamp and five cents per K. W.-hour	Receipts per K. W.-hour by Wright Demand system; sixteen cents first two hours, six cents after	Receipts per K. W.-hour by flat rate of $12 per year
		Cents	Cents	Cents	Cents	Cents
¼	36,500	76.26	79.39	69.3	16.	262.73
½	73,000	38.13	41.25	37.1	16.	131.8
¾	109,000	25.56	28.69	26.4	16.	90.9
1	146,000	19.06	22.19	21.0	16.	65.9
2	292,000	9.53	12.66	13.0	16.	32.9
3	438,000	6.35	9.48	10.3	12.66	21.9
4	584,000	4.76	7.89	9.	11.0	16.45
5	730,000	3.81	6.94	8.2	10.0	13.15
6	876,000	3.17	6.30	7.66	9.33	10.95
7	1,022,000	2.72	5.85	7.3	8.85	9.41
8	1,168,000	2.38	5.49	7.	8.55	8.22
10	1,460,000	1.91	5.04	6.6	8.00	6.59
12	1,752,000	1.59	4.72	6.33	7.66	5.48
16	2,336,000	1.19	4.32	6.0	7.25	4.11
20	2,920,000	.95	4.09	5.8	7.00	3.28
24	3,504,000	.79	3.92	5.67	6.83	2.74

hour to twenty-four hours per day, and the corresponding amount charged consumers under different rate systems. The average receipts for current were .12518 per kilowatt-hour, which, if plotted on this curve, would simply be a straight line from the vertical axis parallel with the horizontal axis at the altitude .12518 cents.

This gives us a profit-and-loss curve as illustrated.

I also give graphic load chart of these same data.

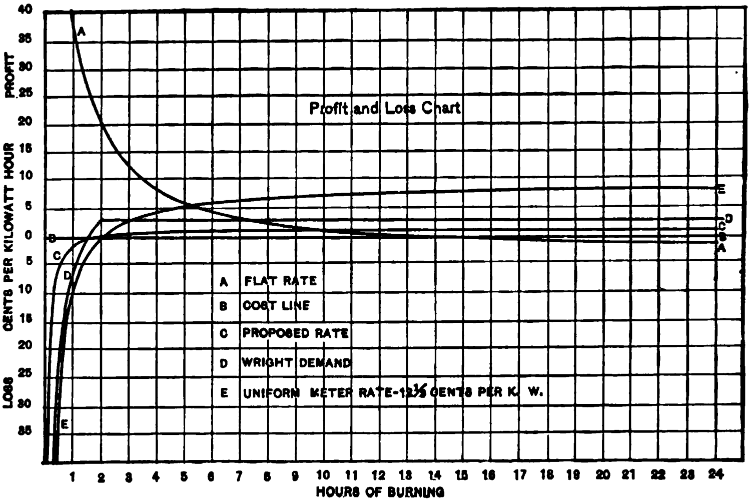


Now, I expect to be told that

First—I shall drive away consumers;
Second—That I shall depress the peak;
Third—That the people will not favor the change.

I answer to the first of these objections: (a) that certain customers will be driven away, but they will be the unprofitable ones; (b) that enough of our present unprofitable ones will remain with us and will pay what their service costs; (c) that many of our present unprofitable consumers will abandon the use of gas and oil for long-hour consumption; (d) that many other customers will be attracted by our low kilowatt rate.

To the second objection: (a) I will admit that I will depress the yearly load peak for a given number of consumers, which I claim will be an advantage rather than a detriment; it will reduce interruptions of service, better our regulation, and decrease our line and transformer losses; (b) but it will encourage a more uniform load peak throughout the year, lessen the investment for meters, and increase the accuracy of their registration by enabling size installed to be intelligently selected.



Your third objection is a matter of education, and I ask (a) if you expect a reduction in your telephone bill if you do not use it for a month? (b) is not this system the nâtural step to take in changing from flat rates? (c) is the consumer whose bill is reduced apt to object to the change? (d) can you afford to supply the consumer whose bill is increased at less than his schedule charge? (e) are not all objections to this proposed plan due to having improperly educated the public in the past? If you break your leg, you expect the surgeon to cause some pain in setting it, and this pain is chargeable to the accident and not the surgeon.

I claim for this system:

First—Greater uniformity.

Second—A tendency to produce a better yearly load and better daily load.

Third—An encouragement of long-hour lighting and the use of current for other purposes than lighting.

Fourth—Ability to meet competition of isolated plants.

Fifth—A weeding out of unprofitable business.

Sixth—Better satisfaction to consumers.

Seventh—A lessening of cost of production.

Eighth—A lessening of cost to consumer per kilowatt.

Ninth—Ability to dispense with high-priced, trouble-breeding, rate clerks.

Tenth—Ability to give better regulation.

Eleventh—A lessening of difference between registration of station and consumers' meters.

If desired, a clock arrangement can be used to throw a heavy conductor in series with the demand meter, to encourage heavy use of current at desirable hours of the day.

A deduction for power users can be made from the kilowatt rate for incandescent-lighting current, to compensate for lamp renewals and regulation, and thus all classes of consumers can be supplied at a uniform rate.

Many isolated plants are installed simply to use idle capital. A trust fund could be created, and any customers wishing to provide the investment included in the charge for "readiness to serve" could be accommodated. I would not object to a deposit large enough to pay their entire charge for readiness to serve, allowing them the same rate on their money as paid on the bonds. A fund of this sort would do much to silence their objections, even though they should not take advantage of it.

The opportunities for development in the central-station business are simply unlimited. The instances are very rare where a properly equipped central station cannot profitably sell current at less than the cost of production in an independent plant. There is no reason why we should confine ourselves to supplying small powers. Nothing should be too big for us to wrestle with. Many gas companies to-day sell more gas for fuel than for lighting, and the supply of power to the electric business should be what the supply of fuel is to the gas business.

If the individual aggregate demand of your consumers is greatly in excess of your maximum demand, I see no reason why your charge to them for readiness to serve should not exceed the cost, provided rates yielding a profit should prove profitable to the central station in the long run.

The lower the rate at which we can give consumers current, the greater our opportunities for extending its use and finding new uses for it. There is a good deal of human nature portrayed in the story of the salesman who told his rural customer that a certain stove would save half the fuel, to which he replied: "I guess I will take two of them and save all of it." Better have several thousand customers planning means to use additional current, and thus diminish their kilowatt cost, than to attempt to do all of this planning yourself and then have to convince them of the wisdom of your ideas.

Fan work, ventilation, refrigeration, pumping, decoration, sign lighting and miscellaneous power work can be enormously developed by a low rate. As you decrease your rate, your consumers decrease their vigilance of consumption. A low rate will tend to put many basement, hall and bathroom lights in constant use. Many people are too lazy to even "press the button."

Our salvation from many evils is to have the public understand that fuel and labor are not our only items of expense. The public get an inkling of the expenses of these items and conclude that the biggest part of our receipts is applicable to dividends.

Does any one, in figuring service from isolated or municipal plants, ever include interest, depreciation and taxes? Is there any better way to keep this in the public mind than by charging a certain amount for "readiness to serve?" If they have to pay for readiness to serve, they will include this item in their estimates when they start to figure what it will cost them to serve themselves.

I recommend this system to you as one that will develop your business, repress agitation for municipal ownership and the granting of competitive franchises, meet the competition of isolated plants and other means of illumination. I believe it will reduce the cost of production, better your load factor and regulation, lower the kilowatt cost to the consumer, increase the stability of your business, strengthen your securities and increase your earnings; in short, prove a panacea for most of the ills to which the average central station is heir.

DISCUSSION

THE PRESIDENT: Gentlemen, this interesting paper is now open for discussion.

MR. DOHERTY: The necessity for a fixed charge for readiness to serve is best illustrated by an example: In a certain city with which I am familiar, is a church having a connected capacity of 300 lights. This church has been lighted but one night each year for some years back, and that night is Christmas Eve. The development of the central station in that city costs $300 per kilowatt. The maximum demand of this church would be something more than fifteen kilowatts, which represents an investment of $4,500 of the capital of the central station that must be reserved for the use of this church.

With interest at five per cent and depreciation five per cent, you have an expense of $450 per year for these two items, to say nothing of transformer and meter shunt losses, expense of reading meter, etc. Assuming five hours' consumption on this night at twenty cents a kilowatt hour and a minimum charge of $1 per month, the income is $26 per year; a loss of $424 on two items alone of your expense account.

MR. FERGUSON: As I represent a company using a modified form of the Wright demand system, I should like to say a few words about Mr. Doherty's objections to the Wright demand system. What I am about to say is in my capacity as a central station man, pure and simple, and not from any other standpoint. Mr. Doherty states that the Wright demand system meter is not suited to all classes of customers. I think that may be true in part. It is difficult to find a system that is suited to all classes of customers; in fact, I know of none that will get you all the business. Mr. Doherty's method will not get you all the business, as you can see by referring to his table. If you take the table on page 316 of the paper, you will see that the receipts per kilowatt hour from a customer that uses the service for five hours a day is 8.2 cents. We all know that you can not take out an isolated plant on 8.2 cents per kilowatt hour, and many of them have only five hours' use. If you take ten hours' use the cost is 6.6 cents, and you can not take out large isolated plants at that price. I think there is no price on that list, even for twenty-four hours' service, that will take out the large isolated plants. You can not take them out unless you make a price of four cents. The lowest price Mr. Doherty names is 5.67 cents. It seems to me that his system is not suitable for all classes of customers. Further than that, his system will not apply, to a very great extent, to residences. It will apply to some, but you will not get all the residences, because the rate will be too high. Take, for instance, a house (I did not see Mr. Doherty's paper until just before this session, and so I have to give figures somewhat at random) that has sixty lights in it, like my own house. I have no Wright demand meters in the house, because I buy my current from another company, which sells on the ordinary discount basis; but assuming that the maximum is twenty lights, the charge would be twenty times $1.50, which would be $30, plus $3 for the service, which makes $33, plus $3 for the meter, making $36, which is the minimum charge to start with if I understand Mr. Doherty correctly. We will assume that the consumption in that house will be $60 a year at twenty cents per thousand watt hours. Then the cost at five cents, according to Mr. Doherty's scheme, would be $15 for the current, which, added to the $36, would make $51, or a discount of about fifteen per cent. There are lots of companies doing business in residence territory on a fifteen per cent discount from a twenty-cent rate; but I doubt if they will continue much longer, as the tendency of rates is much below that and only a comparatively small business can be done at that discount. The maximum I have taken is a favorable one, and one-third of the connected load. I have not taken an extravagant case, but one extremely favorable to Mr. Doherty's system.

To return again to the objections. In his attempt to show that the Wright system is not suited to all classes of customers, Mr. Doherty states that the short-hour consumers do not pay full cost of service, and long-hour consumers must be made to pay more than the cost of service and proportional amount of profit to compensate for loss on short-hour consumers. In answer to this I would say that, in the first place, we are limited in Chicago to a maximum charge of twenty cents per thousand watt hours. We are obliged to stand on that rate; we can not go higher. I would say further that the percentage of customers, out of a gross business of $442,000, on the Wright system who did not receive any discount was seven per cent; showing that the system has an efficiency of ninety-three per cent in regard to this one objection.

The second objection is that a liberal installation is apt to be discouraged. I do not see how that can be any objection. I do not think the objection is well founded, because the Wright system has absolutely nothing to do with the installation; it has to do only with the number of lights used at any one time, or the maximum demand, and it is absolutely independent of the number of lights installed.

The third objection presented by Mr. Doherty to this system is that a liberal consumption is also apt to be discouraged for the sake of keeping down the maximum demand. It is to his interest to keep down the maximum demand. He also says that consumption is curtailed to lower demand registrations at seasons when peak is not undesirable. That objection will probably be true in the ordinary Wright demand system, but is not true in the system as used in Chicago, because here we make a lower rate in the summer time than we do in the winter, and therefore encourage the use of our service at a time when the peak is not objectionable.

The fifth objection is that this system is apt to occasion the greatest possible fluctuation of peaks for different months of the year, while a uniform peak is desirable. I will say that this objection, like many of the others, must be entirely theoretical, because conditions in Chicago and in Boston do not show that this is the case. The load curves in Chicago and Boston have changed only in one way, and that is to broaden the curve, and not to introduce a peak at other times than was formerly the case before the installation of the system.

The sixth objection is that the charge bears no exact relationship to the cost. I think if the word "no" should be taken out and the article *an* inserted, the statement would be fairer; because we are not dealing here, in this association, in the matter of selling our current, with things that are theoretical only, but with things commercial; and my claim is that the Wright system is a commercial system, although you may be able to find small theoretical points that are objectionable. In fact, I think that Mr. Doherty's own arguments in regard to his system prove that his system does not bear an exact relationship to the cost.

The seventh objection is that errors in reading can not be rectified. I presume what Mr. Doherty refers to is that after the reading is once taken and the meter tipped back, you have no means of telling what the reading was before. This has been true for years with the chemical meter, and all the Edison companies have done a profitable business with the chemical meter. I think, therefore, that this objection is trivial. The eighth objection is that accuracy of readings can not be demonstrated. The meter is very readily tested and we can show at any time what the meter will do, and I think that objection is small.

The ninth objection is that the equipment is expensive. It seems to me that Mr. Doherty's great objection is to this instrument; I do not know why, but it seems so, and I think the objection is not well founded. The cost of the investment in Chicago for something like 6,000 meters represents three-tenths of one per cent of the total investment. The cost is about $40,000 for the meters installed. The interest on $40,000 at six per cent is $2,400 per year. For a device that will make out the bills for you instead of necessitating your parleying with every customer that comes in, that $2,400 is a small amount paid. When you are doing a business of $442,000 a year, you can afford to pay $2,400 a year to know that your current is being properly sold. I might say, incidentally, that the substitute that is offered will cost some money. I think a circuit breaker will cost pretty nearly as much as the meter. It seems to me that the device that Mr. Doherty is going to use—a fuse and circuit breaker, with a bell on it—is an experiment, and savors of the laboratory. We know that fuses are not always reliable, and will blow out sometimes from unknown causes, heating of terminals, and that sort of thing. It does not seem to me that it is a commercial thing to introduce a piece of apparatus to put a man's lights out or make them wink. That might do in a small town, but would not do in a large city.

The tenth objection is that the Wright demand system is the most complicated of all two-rate systems and is the least apt to be fully understood by the consumer, and, therefore, not apt to inspire the consumer with confidence. That is a pretty broad statement. I would say, in general, in answer to that objection, that we have had no difficulty in educating our consumers in order to have them understand what the system is like. We occasionally have some people that do not want to understand it, such as the saloon-keeper. I think Mr. Doherty will have as hard a time to teach the average saloon-keeper the merits of his system as we should have to teach him the merits of ours if he is bent upon not understanding it, as we find in some few instances.

The eleventh objection is that the cost of inspection is increased. I have not the figures at hand, but asked the superintendent of one of our districts, just before the paper was read, what it cost in his district, and he told me that in a district where there are 3,000 meters the expense is about $30 a month for inspection. That is an objection that can be easily disposed of.

The twelfth objection is that it is possible for the company to be defrauded by collusion between the inspector and the consumer. I think it is rather tough to put that on the meter when you have bill clerks in your accounting department who can rob you right and left. What is to prevent the bill clerk from making out the bill differently from the way in which it comes from the meter department? What is to interfere with the meter clerk's changing the meters? Is it fair to lay the blame for these things on the instrument? You can find troubles of that kind in any business if you employ men that do that kind of thing.

The thirteenth objection is that the Wright demand system does not eliminate the necessity for arbitrary reduction in rates. I would say in answer to that objection, we do not use the Wright system for isolated plants. I do not think you can find any system that can be used for all your customers. Mr. Doherty has not said a word about selling current on his system for power purposes, and a glance at the tables will show you that you can not sell power under that schedule. We make a practice of selling current to large consumers who will ordinarily operate isolated plants at a rate much lower than that under which the customer would come on the Wright demand system.

The fourteenth, and last, objection is in regard to the legality of the system, and I suppose that is an open question. Possibly Mr. Doherty has looked into that; I have not. We have never had to go into court and sustain our position in regard to its legality.

In general, I should like to say that the proof of the pudding is in the eating. We are doing a business on the Wright system of $442,000 00 gross, yearly, or $291,000.00 net, which shows an average discount of thirty-three per cent, and we find that it satisfies all our customers except the large consumers-that would ordinarily operate isolated plants. We apply it to our business satisfactorily, and it has been demonstrated that the system, as employed in Boston and Chicago, is a commercial success. I should not have recommended it to the company had I not thought it a good thing. I made a trip to Europe purposely to look into the system, and reported to our president that the system as used in Brighton, England, could be Americanized to suit the commercial conditions in this country. After careful consideration by a number of us in the company, it was decided that we should adopt it. It was decided to use it purely because we thought it a good thing. One reason why we did not adopt the maximum demand in the winter, which Mr. Doherty will use in his system, was that we could not tell in advance what it was going to be. If a man comes on the system in June, how can you tell what his maximum is to be? You cannot make a contract with him, unless it is a blanket contract, based on his December maximum. It is well enough the second year. The reason why the system based on the maximum demand is used in England, is because there the people pay their bills once a year.

I will withdraw one statement that I have just made, as I find that Mr. Doherty does mention a reduction for power users. Even with these deductions his price is too high.

MR. GILCHRIST (Chicago): I will take up this discussion at the point where Mr. Ferguson left off. He began with a refutation of the objections to the Wright demand system. I will begin with a confirmation of the arguments in favor of it. It seems to me, as I look over pages 299 and 300 of the paper, and see how very little space is given to the arguments in favor of, and how much space is given to the arguments against, the Wright demand system, that the old adage that quality supercedes quantity should be taken very much to heart. In any system that you adopt you must study the conditions you have to meet. There can be no Wright demand rates, if you please, adopted generally for every station in the United States. The system has to be modified so as to be in accordance with the statutes of the state, with the conditions under which you are meeting competition, and with the rates that have prevailed before its adoption. We believe, in Chicago, that the Wright demand system approaches not only as closely as any of the other systems enumerated, but as closely as any system that could be devised, to an equitable registration and charge for current; it certainly approaches as closely as would the system proposed by Mr. Doherty. Mr. Doherty has the advantage of taking the costs from a station and establishing a theoretical basis of charging without any relation to the question as to whether or not he can do business on that basis; whether or not he can bring his customers up to it.

In adopting the Wright demand system as a practical proposition, it is necessary, as I say, to take your conditions and modify the theory of the systems to meet them. You can take the Wright demand system in the abstract, and advance prices that will be correct theoretically and that will follow the line of costs from one quarter of an hour to twenty-four hours very closely; but it is a question if there is any city on the face of the globe in which you could start in fresh and enforce those conditions. The thing that naturally appeals to me in considering any basis of charging is—How will the consumer look at it? The consumer of electric light is like the consumer of anything else. If you want to sell a man electrical supplies, you must educate him to the fact that he needs electrical supplies; and you must do the same thing with electricity. It does not seem to me that it would be a possible thing to insist upon getting an agreement from a prospective customer, whether he remains a month, six months, or a year, to pay you for a certain stipulated amount of current. If he is using the light, he may do it; but if you are to get him from the outset, you must get him to use the current first, get him into a familiarity with the advantageous points of your system, and you must do it by a method that attracts him very strongly. My experience has been, in running the contract end of a business where the Wright demand system has been used for over two years, that it is very satisfactory to the customers. No matter what customers as a whole may say regarding meters, the average sensible man believes in meters; he believes they are right. If a meter is inaccurate, it is more likely to be inaccurate against the company than for it; and the company is not likely to maintain and use a meter that is going to be against the company. Admitting that, it comes down to the question of the integrity of the officers of the company, as to whether they would take a meter that would register accurately and bias it so that the customer would be the loser. A consideration of the integrity of the men that represent the company, and a little courtesy in showing the customer the meter devices, will, I think, without exception, with any fair-minded man that talks to you without prejudice, satisfy him that the meter devices are all right. They like the demand meter because there is something mechanically definite to tie to. That is why I believe in it as against the New York system, a system that takes a certain number of lights as the probable maximum that will be required, or that takes the connected load. The latter is manifestly unfair; and to take the probable maximum,—which scheme may be adopted by people who favor the Wright demand system but object to the cost of the meters—the customer feels is theoretical. No one knows whether he has used the lamps or not. When he can go and see the meter working in its simplicity, and realize what the maximum has been, he not only feels that the basis of charging is fair, but he can immediately see the reason why he should pay more under such a system than his neighbor. The point is that the meter pays well for itself in that one respect. I believe, without question, that the system encourages long-hour consumption. That has been our experience. Electric-light customers, like all other people, will be dense when a thing does not meet their views; but it is surprising how quickly a man, who you have no idea will grasp the proposition, will see through the demand proposition if it favors him, as it does in a majority of cases. I am a firm believer in the fact that any man capable of running a business successfully in America will understand the Wright demand system very quickly.

Mr. Scovil: It seems to me that the objections made are not well founded. The principal laid down —that each customer should pay his proportion of the fixed charge—is unassailable. The criticism of the system is mainly of the application Mr. Doherty has made of it to the business of one special small station, and because this application does not fit certain other conditions they have drawn certain conclusions. I think, however, that one of the objections to the system is the difficulty of making a practical application of it; and another point is that it lays a central station man liable to competition from incoming parties, who will say: "This station is charging you to-day a certain fixed rate per lamp installed, based on its present capitalization. If you will only let us in here we will do that for one-half this fixed charge, and charge you the same rate for current."

In a good many cases electric light companies are held down by ordinance. In Cleveland we have an ordinance that does not allow us to charge over twelve and one-half cents per kilowatt hour. We considered very seriously, before we came to a conclusion about the best method of charging in Cleveland, the question of adopting this very basis that Mr. Doherty proposes. It was first suggested to my mind by the basis of charges that the Niagara Company proposed to make for its service. We did not adopt it, because under existing conditions with us we foresaw a good deal of difficulty in putting it into practice; one of these difficulties was that we should have to educate public sentiment (a hard thing to do) to accept a service charge. Mr. Doherty's position is unassailable in the principles laid down as to the proper method of charging for service and current.

MR. ANTHONY: In regard to the Wright demand system, possibly the individual that has to collect the bills and meet the customer after the contract is made, can say something in regard to the situation. The Chicago Edison Company has tried various rates, various methods, various schemes and systems for obtaining business; but surely no system has ever prevailed in Chicago that has given the customer such universal satisfaction, that has resulted in such prompt payment of bills, and that has cost the company so little in the writing off or settlement of discounts or accounts, as the system controlled by the Wright demand meter.

I am not a technical man, and cannot talk from the technical side of this question, but from the commercial side of it; and that is what we are all after—the dollars and cents; to get the most we can out of our business that is fair and right and to collect it promptly. I can say that the results, so far as the customer goes, speak volumes in favor of the Wright demand system. We do get our money in; we explain our bills more readily to the success of the business and the satisfaction of the customer, and if these points are of any value to the system—and it seems to me that they are—I think the same are worth mentioning in this meeting, in view of the fact that our business is as large as it is and that the Wright demand portion of the business is practically one-fourth of our income.

MR. FERGUSON: Mr. Scovil, in what he said, may give the convention an erroneous idea of what my position is on the subject. I agree with Mr. Scovil and Mr. Doherty regarding the church proposition. A church is one of the worst things you can have on the system, and the Wright demand system takes care of that. Mr. Doherty's method is only a modification of the Wright demand system, and contains many of its principles. It gets along without the instrument and uses some other means of getting at the maximum demand.

MR. SCOVIL: How would you manage the church proposition on the Wright demand method?

MR. FERGUSON: If the church had a large load, which would be probable, it would have to use the maximum for a certain number of hours before any discount would be given. Suppose it had one thousand lights, and maximum five hundred; under the system we employ in Chicago it would have to use five hundred times forty-five hours before any discount would be given.

MR. SCOVIL: It would be served at a loss.

MR. FERGUSON: That may be, but it does not affect the Wright system at all. The Chicago system is a modification of the system used in England; modified to suit the American conditions, because bills have to be rendered monthly, and we base our bills on monthly readings rather than on the maximum reading in December. Further than that, in many places in England they charge a fixed amount per year, the same as Mr. Doherty suggests. All these methods follow the principle of Mr. Wright's system, and so there are many things in Mr. Doherty's system that follow the Wright demand system. It is not a question between the systems, but between Mr. Doherty's system and many modifications of the original Wright demand system.

MR. DOHERTY: I think the strongest point about the Wright demand system is the able backers it has in this country. I think the ability of its backers exceeds the merits of the system. I have not yet had an explanation from Mr. Ferguson as to how the Wright demand system would take care of the church. He says they would get no discount. If you take the conditions I gave you a few moments ago, their total bill at twenty cents per kilowatt hour would be $26, where your expenses for readiness to serve would be $450 for interest and depreciation alone. While I admit that I cited an extreme case you will find cases that go all the way from that church to the consumer using current ten hours per day. I will admit that in a certain way there is a similarity between the Wright demand system and the system I propose, inasmuch as each of them differs from flat rates and uniform rates. I do not think there is any other similarity between them.

Mr. Ferguson has seen fit to attack that portion of my paper, which I admit is very weak, where I have cited the conditions in a small station that did not compare with the sources from which I expected opposition Mr. Ferguson has stated that only seven per cent of their customers do not get a discount on the Wright demand system. As the average consumption in the average plant is much less than two hours, and I believe it is usual in this country to make the lower rate at the end of two hours or three hours, the condition that Mr. Ferguson cites for Chicago would not prevail in the other central stations that are represented here; or, at least, not in most of them, and I am talking for most of the central stations and not for a special few that have extremely favorable conditions and in which I honestly believe the Wright demand meter is a great deal more applicable than in the other central stations.

I want to be frank; I want to be honest, and I will say that my main point in this paper has been to discredit the Wright demand meter. Not that I have any animosity against the Wright demand meter or its backers; quite the reverse. I admire the system and its backers; and the Wright demand system has been so well pushed by its backers that they have, in defending their system, done much of the work I should otherwise have done in this paper. Their arguments have been so able in support of the

Wright demand system that they have convinced the public that the straight meter rate system is not equitable, and they have gone a long way toward pointing out the errors of the two-rate meter system. In view of the fact that I expected the most opposition from the Wright demand advocates, I necessarily paid the most attention to that particular system in opposition to the one I propose. I have not read all the literature on this rate question, but I believe that I present a new system of rates; but whether it is new or old, I intend to adopt it in certain central stations, and I am willing to stake my professional reputation on the outcome of that system in the long run. If I am mistaken, I will offer my humble apologies to the members of this body; but I put myself on record as believing in that system; I believe it is unassailable. Mr. Ferguson's objections are largely due to the fact that this paper was printed for publication and to be distributed broadcast. If he and I were to sit down privately and discuss this question, much of what he has said would be omitted, because there would be no reason to say it. I see no reason why this system will not apply to residences. I think the beauty of it is that it will apply to anything. You do not care whether a man uses lights in a store or in a residence. If he occasions a certain demand, that means a certain cost for readiness to serve. I still hold that the Wright demand system does not protect the station from loss on short-hour consumers. There is no object for a man to increase his consumption from a half hour to one hour, for he does not get a discount until he gets to two hours a day. Then, there is a question of the legal limit to the rate at which we can sell electric current. That is what I want to avoid where

I am operating, and I want to get my conditions so that they cannot compel me to sell at a loss; and I can demonstrate to the satisfaction of the members of this body that there are certain consumers to whom you cannot supply current at twenty cents per kilowatt hour and supply it at anything but a loss. The Wright demand system affords you no protection against these consumers.

I cannot agree with Mr. Ferguson in his belief that the installation is not apt to be curtailed for the sake of depressing the maximum demand. I am inclined to think that on the Wright demand system a householder would be apt to leave lights out of his basement and out of the servants' rooms, to prevent these lights being lighted at the same time as the others and the bill thereby increased; while with the system I outline nothing happens if it is exceeded, and their attention is called to the fact at the time, and there is no chance for dispute. I speak from an experience of eighteen years in the lighting business, and the people to whom I sold gas are the same people to whom we are selling electric current to-day. They are just as hard to handle, and they stand for just as much and for just as little. Mr. Ferguson speaks of the many variations of the Wright demand system. I did, too, with special attention to the "many." I tried to get a system that would be universally applicable, but I do not think there are two central stations in the United States in which the Wright demand system is used in the same manner. I do not think there are any two stations in the United States that agree exactly as to how the Wright demand system should be used. I cannot agree with Mr. Ferguson that we should regulate our base charge, whatever that may be; a charge for readiness to serve, or so much per kilowatt hour on a monthly maximum demand. It is the yearly maximum demand that we are interested in, and I can only assume, unless he has a minimum charge, that if a man leaves his house closed for eleven months in the year and has no bill for those months, he pays in December what his maximum demand indicates.

I still maintain that the readings of the Wright demand meter, as generally used, cannot be rectified if an error is made in their observation or recording. I do not think that to cite the fact that chemical meters were used, is an argument in favor of still using some system whose accuracy cannot be demonstrated. I cannot agree with Mr. Ferguson that your bookkeeper and your meter reader, under ordinary methods, can defraud you. In the plants in which I am interested, the meter readers are rotated each month, and the readings are cumulative. An inspector cannot benefit the consumer by underreading the meter, and he will be detected if he does. If he wants to underread the Wright demand meter, he can underread it and destroy the evidence of his guilt by simply resetting the meter.

I do not think Mr. Ferguson's objection to fuses is well founded. I think you will find that Mr. Ferguson depends a great deal upon fuses, and, so far as I am concerned, I think the fuses are very accurate. I can bring manufacturers of fuses into this room who will guarantee the accuracy of fuses to a greater refinement than is necessary for the system proposed. I think that if Mr. Ferguson were to go out to-morrow to figure on what basis he could afford to supply current for an isolated plant, he could not find a better method for his computation than is outlined in the paper I have presented.

I hope the statement does not appear immodest; it is my firm belief. His objection to my inability to determine the maximum demand for the year is, in my opinion, not well founded. I propose that we allow the consumer to contract for whatever maximum demand he may choose. He would be at liberty to increase that at will, but he would not be at liberty to diminish it except at the end of the year. I think that is an easy solution of that proposition.

If there is anything that will enable us to show the public the folly of competition, it is a system of this kind, where the greater the number of consumers in one central station, the more the charge for readiness to serve can be diminished. There is little or no question in my mind regarding the other features of competition, if it does really exist; and while I dislike to cross swords with Mr. Ferguson in a professional way, I should not hesitate at all to cross swords with him in competition if he were charging on the Wright demand system and I had in use this system that I propose. I think it would result in the station that I represented getting nearly all the profitable business, and would certainly result in the company represented by Mr. Ferguson getting all the unprofitable business; and I should like to ask if that is not a fact.

MR. FERGUSON: You might refuse to take the business that would be unprofitable. We believe in Chicago that we ought to take all the business. In the church proposition, I want you to understand that we should charge the church as much as the law allows. There is no use in our having a system, even if it is theoretically perfect, if we cannot operate with it. We could not afford to charge that church the amount to be allowed under your system, because the law would not permit us to do it. We have two alternatives: to let the business go, or to take it at the price the law allows.

MR. DOHERTY: If you were operating a station under your system and I were operating a station under this system, both in the same city, you would get all the unprofitable business.

MR. FERGUSON: If I sought after it I might get it; but you would not get all the business that is profitable, because your rates are too high.

MR. DOHERTY: I do not see why Mr. Ferguson should object to a charge of $100 to the consumer, $50 of which was for readiness to serve and $50 for current at five cents per kilowatt hour. It would cost him no more than the same quantity of current at ten cents per kilowatt. I do not see why my rate must be any higher than his. It seems to me that if he can disprove my argument, he disproves the whole theory of the two-rate system; that is, by selling additional current at a lower rate, you can increase the hours of consumption and increase the quantity used. So far as the question of the legality of the Wright demand system is concerned, I have referred this matter to an attorney whom I consider competent. I have tried to embody his views in my paper. If he is wrong, I am wrong. As to my own system, I referred it to this particular attorney, and I also referred it to the attorneys of the company in which I expect to adopt this system of charging. Both said that there was no question at all but that it was entirely legal. Another attorney said that in spite of the maximum having been placed at twenty cents a kilowatt hour, he did not believe the courts would compel a central station to supply current to a customer at a loss. If the charge were based on the kilowatt output, we should have to charge on that basis; but if we cared to base it on this plan, we could either refuse to take the business or compel the customer to pay us a sufficient sum to secure us from loss. As to Mr. Ferguson's argument that the bookkeepers can also defraud the company under the meter methods, I wish to say that in the system used in the plants with which I am familiar, there is little or no opportunity for the bookkeeper to defraud the company. The system of checking seems to offer ample protection; but the mere fact that the bookkeeper can defraud us is no argument that we should let down the bars and put every other employee of the company in a position to defraud us. We do not lessen the ability of the bookkepeer to defraud us by using the Wright demand system.

I presented this paper without any wish to offend any of the members here, and for the sole purpose of knowing more about making rates for electric lighting. I am firmly satisfied of the wisdom of the system proposed by me; but if I have said anything that has placed any other system at a disadvantage, I am sorry for it, as I want to give every system credit for its true worth. I find there are more objections to my paper than I expected, and many of the points that I think should receive the earnest attention of every central station man, have not been touched upon. If any of you will read this paper over carefully, you will agree with much that I have said, because it is the result of observation of the existing conditions in many central stations scattered over the country, small and large.

Mr. Ferguson: I want to make one statement in regard to the matter of collusion. There is no reason why you cannot have collusion with a wattmeter as well as with a Wright demand meter. A man can set back a wattmeter.

MR. DOHERTY: How can he if it is sealed?

MR. FERGUSON: Make a new sealing tool. Collusion is as applicable to the Thomson wattmeter as it is to the Wright demand meter.

MR. DOHERTY: In one case a man has to forge a tool, and in the other he does not.

MR. FERGUSON: I will bring to the meeting some tools and seals that have been made and used for the purpose; and I will show the meter records, and show how much the meter was set back and when it was set back. The fraud extended over a period of eighteen months, with a Thomson wattmeter.

MR. DOHERTY: We must look for fraud in the classes of employees that come lowest on our list; but I do not think you can get any electric light man in this room to agree with you that the Thomson wattmeter, when properly sealed and its readings surrounded by ordinary business precautions, can be as easily falsified as the Wright demand meter.

The meeting then adjourned.

SPECIAL EVENING SESSION

ALTERNATING-CURRENT GENERATORS

BY H. G. REIST

Since the general introduction of alternating current followed the extensive use of direct-current machinery, it was very natural that the same type and method of construction used in the latter should be adopted, and revolving-armature generators resulted. With the small sizes that were at first built, and the moderate potentials of that time, these machines were satisfactory, and there was little reason for any change; but with the development of the art, various improvements and modifications suggested themselves, one of the most important being the introduction of machines with revolving fields. These machines offer many advantages of construction and operation, and are rapidly displacing the machines of the older form.

The regulation of the potential of alternating-current machines has always been an interesting problem, and one for which a solution has been eagerly sought for some years. There have been various steps in solving this problem, which may be briefly traced with interest. The first machines were separately excited, but it was soon found that some form of automatic regulation was desirable, and methods of compounding were devised. This was done either by rectifying the line current or a current derived from a series transformer in the main line. For a load with a uniform power factor, this method of regulation is quite satisfactory; but with a mixed load of lighting and induction motors it leaves much to be desired, since if the machine is adjusted to regulate for a load of one kind, it will either over-compound or under-compound for the other condition. If the machine is adjusted to give the proper potential at the end of the line with a lighting load, it will be too low if motors are added; if adjusted for a motor load, it will be too high if lights are operated alone. It was with a view of rectifying difficulties of this kind that the compensated machine was devised. This was so named because it compensates or equalizes for loads of variable power factor, and will give the potential for which the machine is adjusted, whether the load is non-inductive, or whether it is an induction-motor load, or a mixed load; that is, you may have a load consisting entirely of lamps, and the machine will compound to 2,300 volts at full load, or you may have a motor load and the same potential. The same is true if the load consists of half lights and half motors; always with a given load the potential at the generator will keep constant. This is a feature of very great value, as will be appreciated by all that have operated alternating-current apparatus.

As stated above, the earlier alternating-current generators were usually built of the revolving-armature type, the first machines having the winding placed on the surface of the smooth core, but later it was placed in slots of the then so-called iron-clad armature. This allowed of the use of entirely-inclosed armature coils, thus making possible an insulated covering of a quality unknown in earlier dynamo construction; but the supporting of the coils on the revolving armature, either by bands, or by clamps, or by shield rings of various kinds, was always a troublesome matter. The collector rings for the higher potentials have also been a detail to which there was considerable objection, both on account of the difficulty of constructing rings satisfactorily insulated for higher potentials, and also on account of danger to the attendant. It is unusual to find machines having a higher potential than about 3,300 volts of the revolving-armature type, largely for this reason. For very low potentials, on account of the large current to be taken from the collector rings, the revolving-armature machine is also unsuited.

ARMATURE

With the introduction of revolving field generators, many difficulties inherent to the revolving-armature machines have been overcome, and a construction much more satisfactory in every way has become possible. We are now enabled to produce machines that have stationary armature coils, which require comparatively little fastening in the armature, and which may be wound for all potentials, from the lowest to 12,000 volts or more, with entire satisfaction. In the case of high-potential machines, the terminals are usually entirely inclosed, so that it is impossible for the attendant to be injured by them, either from carelessness or accident. On low-potential machines, the feature of having stationary armature coils is just as desirable, as the current is led through stationary parts only, and does not have to pass through brushes. The coils of the armature are wound directly into their final shape and then filled with insulating compound. The insulation consists of a number of layers of tape, the number varying with the potential of the machine; each layer being carefully coated with varnish, thus making a coil insulation practically air-tight and water-proof. On high-potential machines the insulation is so important a matter that it is usual to put only one coil in each slot, and also to reduce the number of slots per pole, so that the total percentage of space occupied by insulation is not too great. This produces a winding in which there is more than one shape of coil. On smaller machines, the so-called "barrel" winding is generally used, because such machines are built of lower potentials—usually 2,300 volts. In this case, only one kind of coil is used, and when the coils are placed in the machine they produce a very symmetrical structure. The armature coils are held in place by wooden wedges, which are easily removed, and which form a thorough protection for the coils in case foreign matter should accidentally find its way into the air-gap. The advantages of stationary coils are very great, as they are not subject to injury from mechanical strains produced by centrifugal force. There are no bands, so their removal is a very simple matter; and, lastly, the ends are free to the air on all sides, instead of being bound down to a supporting head. On larger machines it is usual to arrange the armature so that it may be slid on rails in a direction parallel to the shaft until the armature and field are free from each other and either part is rendered accessible for repairs or cleaning. The extra space required for this purpose is usually very small, since a part of it is always necessary for the collector rings supplying current to the revolving field. The armature core is usually built up of the best quality of thin sheet iron, carefully annealed, and the laminæ insulated from each other by paper or japan.

REVOLVING FIELDS

The revolving-field structure is a detail that has received some of the best thought of electrical-designing engineers for the past few years. The pole-pieces are made of punchings of heavy sheet iron about one-sixteenth of an inch in thickness, with a composition end plate, the whole fastened together by means of rivets, or, in some cases, with bolts. These pole-pieces are fastened to the field-ring by two methods; in belted machines, by means of a projecting dovetail on the pole-piece, which enters a groove in the field-ring and is secured by keys with a very slight taper, so that by light blows of the hammer on this key a very secure fastening is obtained. In the case of slow-speed machines, where the centrifugal force is less and the diameter of the field-rings greater, greater lightness and sufficient strength are obtained by fastening the poles by means of bolts. Except in the very small machines, the field copper consists of a flat ribbon wound on edge, so that the coil is only one layer in depth, the outside surface of which is bare. Every turn is thus exposed to the surrounding air, and it is impossible to have a coil warm on the inside. The surface of the coils being flat, gives large gearing of the turns of the coil on the insulation, thus allowing no opportunity for the windings to shift on each other and to short-circuit. The turns are insulated from each other by sheets of paper. These coils form a striking contrast and improvement when compared with field-coils on machines built heretofore.

FLY-WHEEL ALTERNATORS

By somewhat enlarging the diameter of the armature, the yoke of the revolving-fields can easily be made large enough to serve as a fly-wheel for the generator. This, while making the cost of the generator somewhat greater than if a separate fly-wheel were used, still offers many advantages, so that it will probably soon be the usual construction of the engine-driven alternators. Some of the advantages of this form of construction are that the shocks due to sudden changes in load are directly transmitted from the pole-pieces to the fly-wheel mass, and not, as with the older construction, through the arms of the dynamo spider, through the shaft, then out through the fly-wheel arms; the total weight of the parts on the shaft may be reduced, since only one hub and spider are required; the length of the shafts may be greatly reduced, thus also reducing its diameter, and the size of foundation and space occupied by the machine. This construction, moreover, makes a more compact and symmetrical piece of machinery than if a separate fly-wheel is used.

COMPENSATED GENERATORS

The above general remarks on revolving-field generators apply equally to the line of compensated machines to which I would especially like to call your attention. These machines have thus far been built belted only, and the exciter mounted on the shaft of the revolving field; and in their design all the best features of years of experience have been incorporated.

EXCITER

The exciter of one of these machines has the same number of poles as the generator. They are wound for sixty volts on smaller machines and for 125 volts on larger ones. The poles are stationary nd the armature revolves as is usual in direct current machines. The construction of the exciter is the same as in direct-current, multipolar machines, except that, on account of the small energy necessary for exciting, such parts as the pole-pieces and armature coils are very small. The armature coils in this case are also form made, and assembled into the open slots of the punchings. There are three taps in the exciter armature, which are connected to collector rings on the shaft, on the outside of the bearing on the smaller machines, and between the bearing and the armature on the larger ones, the use of which will be explained later on. The exciter is placed within the shield of the alternator, which allows a construction to be used that does not destroy the symmetry of the machine and which affords protection for the exciter. For direct-connected machines, the exciter is mounted on the outboard bearing of the engine, and is driven by means of inclosed gears. In this way, an exciter may be used with a smaller number of poles than are used on the generator.

BRUSHES

The machine is entirely equipped with carbon brushes, and in all cases there are at least two brushes in multiple, so that any brush on the machine may be examined, cleaned and replaced, while the machine is in operation.

BEARINGS

The bearings used in these machines are the usual spherical, self-oiling, self-aligning bearings, made of a heavy cast-iron sleeve lined with anti-friction metal. The bearing next to the pulley is made especially large, both to insure stiffness of the shaft and to avoid wear and heating. The small bearing next to the exciter has only very light pressures, on account of the long distance between bearings. The arrangement that has been adopted on these machines allows the bearings to be placed far apart, yet keeping the machine as a whole very compact; which is a very desirable feature in machines with two bearings. The oil rings of all the larger bearings are made split, so that they can be readily removed without taking the shaft out of the bearings, if desired.

METHOD OF COMPOUNDING

It is well known that when the load on an electric generator — direct or alternating — is increased, the potential will drop unless the field excitation is also increased. This is due to the resistance of the armature, the inductance of the armature, and the reaction of the armature on the field poles, the latter reducing the amount of effective magnetic flux. The potential at a distant point, where the current is used for lights and motors, falls even more, on account of the resistance and inductance of the line. To compensate for this, direct-current dynamos have been compounded by passing the main current through series coils on the poles and so adjusted that the potential at the machines increases with increasing load. On alternating and multiphase machines the same result has been obtained by rectifying the main or an induced current and using it for the same purpose; and, except for a slight increase in complication, the method is just as effective as on direct-current machines so long as the alternating current is in phase with the potential; which, unfortunately, is rarely the case in ordinary operation, since partly-loaded transformers and induction motors produce a lagging current, which requires a greater field excitation to produce the normal potential. Thus, in all types of alternators heretofore designed, the compounding required for non-inductive load has been entirely insufficient for inductive conditions. With the loads that ordinarily have to be provided for on alternating-current circuits, there are wide variations in power factor, especially in cases where a considerable portion of the load is in motors. The introduction, therefore, of automatic means of field adjustment for all kinds and degrees of load is of the greatest practical value. This is what is being obtained by this new method of excitation, which is based on a radically different principle from anything that has heretofore been employed, and it gives an automatic compounding far superior in results to that which can be obtained by any other known method; at the same time, nothing but the simplest and most reliable mechanism is used; in fact, without any mechanical change or adjustment. The devices by which this result is accomplished are mechanically simple. The shaft of the alternator that carries the revolving field also carries the armature of the exciter. The exciter has the same number of poles as the alternator, so that the two operate in a synchronous relation. Besides being connected to the commutator, which delivers current to the field of the alternator and the field of the exciter, the winding of the exciter armature is connected to three collector rings. Over these collector rings it receives current from one or several series transformers inserted into the lines leading from the alternator. This alternating current, passing through the exciter armature, reacts magnetically upon the exciter field in proportion to the strength and the phase relation of the alternating current. In consequence thereof, the magnetic field and hence the potential of the exciter, is due to the combined effort of the shunt field and the magnetic reaction of the alternating current. The connections between the armatures of the two machines are so made that the poles induced in the exciter armature are somewhat ahead of the exciter-field magnetization, but still so that they will assist the field magnets. The result is that with increasing current the current passing through the exciter armature strengthens the exciter field, and thereby the field of the generator. If the current lags as under an inductive load, the poles produced by the alternating current in the armature come more nearly in line with the exciter field poles, thus strengthening the field more with a given line current. This is so adjusted as to give the necessary rise of exciter potential as the non-inductive load increases, and without other adjustment to give a greater rise of exciter voltage with additional inductive load.

Diagram A, showing the curves of magnetization of the exciter, may enable us to understand a little more clearly the action of the alternating current that is passed into the exciter armature. Curve number one may represent the magnetizing effect of the shunt winding on the exciter, and assuming the fields of the exciter to be so placed that the magnetizing effect of the current through the armature has its maximum directly under the pole-piece, its effect might be represented by curve number two. It will be understood that this magnetic effect is stationary in relation to the exciter pole-pieces, since the alternating current passed into the exciter armature is synchronous with its speed, and is passed in such a way as to cause the magnetic wave to move in the direction opposite to that in which the exciter turns. In this case, the combined effect or the sum of the two, will be represented by curve number five; but ordinarily the magnetizing effect in the armature is shifted with reference to the magnetizing effect of the pole. This is readily accomplished by turning the field structure of the exciter into such a position that the magnetizing effect of the armature leads the magnetizing effect of the field, as shown by curve number three, in which case it is shown to be ninety degrees ahead of the poles. Now, combining curve three with curve one, it will be found to produce curve six, which has a higher magnetic effect than curve one alone. Therefore the potential of the exciter, and also of the alternating machine, is increased. If, now, curve three represents the magnetic effect produced with a non-inductive load, it will readily be understood that with a lagging cur-

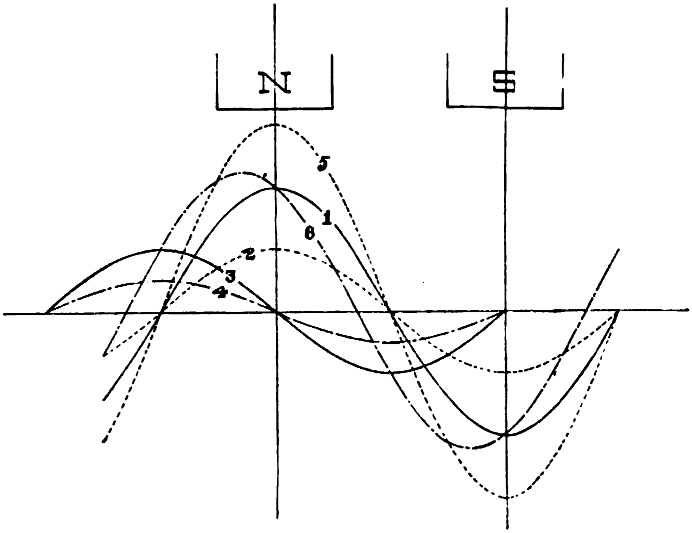


DIAGRAM A.

rent—that is, as the power factor decreases—the magnetic effect will shift from the position occupied by curve number three toward the position occupied by curve number two, which would in this case represent the position of the magnetic effect of the same current with the power factor zero. As the curve shifts in position from number three to number two, the sum of this curve combined with curve number one, which we have assumed to remain constant, will shift from the value of curve number six to curve number five; that is, the magnetizing effect will gradually increase as the power factor of the circuit decreases, which is the essential feature in compounding for a load with a variable power factor. For less than full load, the current in the series transformer will be smaller, and its magnetizing effect will be less; but its position will remain the same as is shown, for instance, in curve number four. Assuming, now, the non-inductive load to produce the magnetizing effect as shown in curve number two, it will be seen that when the field is placed in the position shown in the figure a maximum magnetizing effect will be produced, and if shifted toward number three—or it will be equally true if shifted to the right—the sum of this curve and curve number one will gradually be reduced. Until after it has been shifted ninety degrees, it will have the value of number six; and if shifted ninety degrees more, until directly opposing curve number one, the combined effect will be a reduced curve about equivalent to curve number two. Diagram B shows curves at the potentials of the terminals of the alternator produced by setting the exciter poles in a variable relation to the winding on the generator. Curve number one represents a series of such potentials. Starting from a negative value, it increases to a maximum, and then again diminishes. If the machine is loaded with a current whose power factor is less than unity, the maximum effect, as well as the whole curve, is reduced, and is shifted to correspond with the lagging current, as is represented by curve number three. It will be noticed that these curves have a point of intersection, which is the correct point for setting the exciter fields, since at this point the compounding is the same for a non-inductive load as for an inductive load. The curve of a load with a power factor between number one and number three, would fall between these curves, and would intersect curve number one at the same point, so that this point of setting remains approximately true for all values of power factor. It will be seen from these curves that it is possible to so adjust the machine that it will

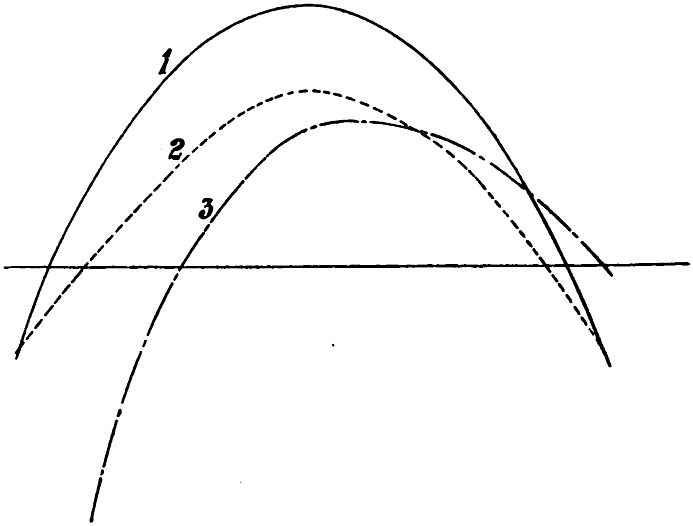


DIAGRAM B.

compound for a higher potential with an inductive load than with a non-inductive, or *vice-versa.* Curve number two represents the maximum potentials of a single-phase load corresponding to about seventy-five per cent of the three-phase full-load rating of the machine, and using the same series transformer. In this case, the maximum compounding is not so high as in the case of three-phase current. This curve also intersects the three-phase inductive load curve number three, so that by setting the exciter fields to the intersection of these two curves, we have a correct compounding for a non-inductive single-phase load and for an inductive three-phase load of a given power factor which is usually about eighty-five per cent.

TESTING

All these machines are tested before being shipped and are marked so that they can be set for either direction of rotation for use with lights connected either in one circuit—that is, between two terminals of the machine—or for lights connected in all three terminals, and, of course, for induction motors connected in all three circuits in either of the above cases.

MULTIPLE OPERATION

When machines are to be operated in multiple, the connections are made to equalizer bars, as is shown in the diagram. They operate in this way very satisfactorily, not the least trouble being experienced. It is possible to operate machines in multiple with different potentials on the exciter.

USES OF MACHINES

As described above, these generators may be used very satisfactorily as single-phase machines for a lighting load on two lines and motors placed between the terminals and the third wire. In this case, the machines are so adjusted as to give a correct potential on the lighting circuit, whether the load is due to a lighting load or a motor load. For small stations, this is a very desirable mode of installing a plant, as only a single lighting circuit is necessary, and the attention given to the machine can be reduced to a minimum. A second method of installation, which has found considerable favor of late, is to install a 240 volt generator that is Y-connected and that has a fourth wire brought out from the common connection. The lights on a machine of this kind are placed between the neutral wire and the three terminals of the machine, so arranging the lamps as approximately to balance the load. This, however, is not very essential, as the unbalancing effect with this arrangement is almost negligible. For factory distribution work, this is a very convenient arrangement, as no transformers are needed, and the power and lights are distributed from the same circuits with a minimum amount of copper and with almost perfect regulation. The usual method of distributing a general system of lights from three-phase generators is to transmit the current over the line by means of three wires, and to transform with the transformer primaries connected delta, and the secondaries Y, connecting the Y connections with a neutral wire and the whole to a system of secondary mains, and approximately balancing the lights in each important installation. In this way a very efficient distribution of the power is obtained with a minimum amount of copper, and the generators are used to the best advantage, as all branches are fully loaded and motors can be installed at any point. In large installations it is usual to have potential regulators in each branch, to take care of slight unbalancing that may occur. These regulators may be made to operate automatically, keeping the constant potential at some distant distributing centre, if it is so desired, or at the station. Two general types of potential regulators are used for this purpose; the

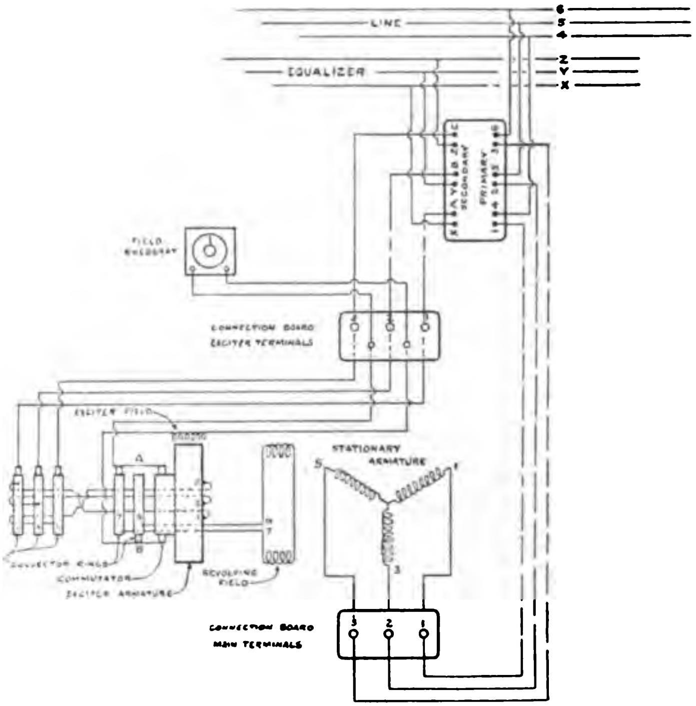


DIAGRAM C.

magnetic regulator, which is used in smaller sizes up to about six kilowatts, and the compensator regulator, which is used on large sizes. In connection with the compensator regulator, an ingenious switch has been devised, which snaps from point to point, carrying current momentarily through an arc, which, however, is interrupted immediately when the second contact is made.

Another use to which this machine can be put, is in the operation of series alternating inclosed-arc lamps, which are so largely coming into use at the present time in connection with the constant-current transformers. Here the load is quite inductive, and it is hard to operate with incandescent lights without hand regulation, but the machine takes care of such loads perfectly.

In conclusion, I will say that I have seen a seventy-five-kilowatt belted machine start a fifty-horse-power induction motor belted to another machine, so that it had a considerable load, with a fluctuation so brief on the lights as not to be noticed unless it was specially looked for; the voltmeter needle swinging, perhaps, five volts for a very small period of time—say, one-tenth of a second—coming back again to its normal voltage, or, in fact, to a higher potential than before, on account of the compounding, in a surprisingly short time. On observing the tachometer on the generator under these conditions, it was found that it also fluctuated, possibly due to the stretching of the belt as the load was put on; thus my conclusions are that there would be actually no fluctuation under these conditions with constant speed.

ORDER OF BUSINESS

THURSDAY, May 24th, 1900

FIFTH SESSION, 10.15 A. M.

1. Report: Committee on Grounded Circuits
2. Report: Committee on Amendments to Freight Classification of Electrical Apparatus and Goods
3. Report: Committee on Standard Rules
4. Paper: "Automobiles as Source of Revenue for Central Stations." By ELMER A. SPERRY
5. Paper: "Combination of Electric Lighting, Power and Railway Work." By R. S. FEICHT

EXECUTIVE SESSION

1. Report: Committee on Nominations
2. Report: Secretary and Treasurer

FIFTH SESSION

The convention was called to order by President Carnes at 10.15 a. m.

The president announced the first business before the meeting to be the report of the committee on grounded circuits, of which committee Captain William Brophy, of Boston, is chairman.

In the absence of Captain Brophy, Mr. Davis read the report, as follows:

REPORT OF COMMITTEE ON GROUNDED CIRCUITS

To the Officers and Members of the National Electric Light Association:

GENTLEMEN: Your committee to whom was assigned the subject of "grounding the neutral wire," have attended to their duty, and respectfully submit the following report:

The two remaining members of the committee feel that they must at this time call attention to the fact that they have been deprived of the aid and counsel of their chairman, the late lamented Lieutenant S. Dana Greene, whose noble spirit took its flight heavenward on that crisp, cold winter night when he and his estimable wife went unwittingly to their death on the treacherous ice and chilly waters of the Mohawk river. The news of the tragic death of our honored associate, friend, and fellow-worker in the electrical field, together with that of the one dearest to him in life, came to all of us as a stunning blow, but more particularly to us, his associates on this committee, who depended so much on his experience and counsel in the performance of the duty assigned to us. A fitting eulogy will no doubt be pronounced at the proper time by some one better qualified than the members of this committee to set forth properly the sterling worth, steadfast friendship, and many virtues, of our late friend and associate, but we beg the privilege of laying our humble wreath, in the form of this slight tribute to his memory, on the little green mound under which all that is mortal of Lieutenant Greene now rests.

The grounding of the neutral wire in direct-current, three-wire, low-potential systems has been a very much mooted question in the past. Some very eminent professors, nearly all fire insurance officers and inspectors, and some prominent workers in the electrical field, have argued against it as being an extremely dangerous practice, and one that would be sure to increase the fire hazard and render the business of fire insurance less profitable. Others, less prominent, perhaps, but having more practical experience with the actual operation of three-wire systems, took the opposite ground, believing no harm could result from the grounding of the neutral wire outside buildings supplied therefrom.

Nearly all fire insurance boards have issued their edict against this practice; but, notwithstanding their opposition, it is now almost the universal practice to ground permanently the neutral wire. Experience has shown that this practice has not increased the fire hazard or losses by fire, but, on the contrary, it is fair to presume that it has decreased both hazard and loss.

A three-wire system, with lamps, motors, etc., in multiple, whether overhead or underground, extending over a large area of territory, must, owing to bare connections in the case of underground feeders and mains, and on overhead conductors insulation that is not impervious to moisture, offer a very low absolute insulation resistance. And, as a matter of fact, leakage to ground over the entire system cannot be prevented. Such being the case, your committee believe that the grounding of the neutral is a very great measure of safety, and by no means a menace to property by increasing the fire hazard. Little need be feared from low resistance grounds, and by grounding the neutral the danger from high-resistance grounds is reduced fifty per cent, because the difference of potential between positive and negative conductors and the ground is the same as that between those conductors and the neutral. Again, so long as a high grade of insulation is maintained on wires, fixtures, etc., within the walls of buildings, little danger need be apprehended from the failure of the insulation of the feeders and mains on the outside, whether they be over head or under ground. The highest grade of insulation of interior conductors should be insisted upon by every station manager, and current should not be supplied to any system of conductors the absolute insulation of which is not all that it should be.

Strict attention to this very important matter will result in a very great reduction of the number of fires honestly chargeable to electrical causes.

A strict interpretation of the instructions given to your committee would lead them to believe that their duties ended with a report on the "grounding of the neutral wire," but as the matter of grounding one side of secondary circuits in transformer or alternating systems has been for a number of years, and is now, occupying the minds of the members of this association, and others who claim to be equally interested, your committee have assumed that this matter was intended to be included, and have given it their earnest attention.

From the time of the introduction of the transformer system, fears have been entertained by a great many that accidents to persons and destruction of property would result from the failure of the insulation between the primary and secondary coils of transformers. To some extent, such fears have been realized, as deaths and fires have resulted from the passage of the primary currents over the secondary circuits, and in each case that your committee have investigated, no evidence of the escape of the primary current over the secondary mains was given by an increase of candle power of the lamps, or otherwise, until fatal accidents occurred; then, and not till then, was it known that the insulation between the primary and secondary coils had failed.

Various plans have been proposed and devices tried to prevent accidents from this cause, the most effective step being the improvement of the insulation of the transformer. The grounding of the outer case, connecting the middle of the secondary coil to ground, and a grounded magnetic shield,—have all been tried to some extent and with varying degrees .of success. Where transformers are placed in manholes and connected to underground lead-covered cables, the case can be securely grounded to the lead covering of such conductors; but when they are placed on poles, structures, roof and walls of houses, it is very difficult, if not impossible, to connect either coils or case to a good and secure ground.

Could this end be gained, the liability of breaking the ground wire would be very great, and when broken such wires would be a source of danger.

No magneto-electric device for automatically grounding the secondary in case the high-potential current passes over the same, known to your committee, has thus far proved reliable. Those kept constantly in circuit, owing to their almost constant consumption of energy, are objectionable, while those that depend on a sudden increase of voltage are unreliable.

While your committee feel that the permanent grounding of one side of the secondary is not an absolute preventive of accidents to person and property, yet they firmly believe it is a step in the right direction, and if adopted will add greatly to the safety of the public and reduce the hazards attending the transmission of electrical energy by what is known as the alternating or transformer system.

Respectfully submitted,

Committee { WILLIAM BROPHY
JAMES I. AYER

THE PRESIDENT: Gentlemen, this report is before you for action.

MR. NEAL: I move that the report be accepted.

The motion was carried.

THE PRESIDENT: The next report is that of the committee on amendments to freight classification, of which Mr. James I. Ayer is chairman. Mr. Ayer was unavoidably prevented from attending the meeting, but his report is here.

Mr. Davis presented the report as follows:

REPORT OF COMMITTEE ON AMENDMENTS TO FREIGHT CLASSIFICATION OF ELECTRICAL APPARATUS AND GOODS

GENTLEMEN: After numerous interviews and voluminous correspondence with the Central Traffic Association at New York, we have succeeded in getting the same definite answers that were embodied in our report last year, namely: that the railroads did not see their way clear to harmonize the classification of electrical apparatus with that of other merchandise. They did not use these words, but they refused to take action, and the expression exactly covers the case.

Your committee sees no possible hope for justice at the hands of the representatives of the railroad company through any application of ours.

The Interstate Commerce Commission has expressed a willingness to listen to our statements, but has coupled with that expression the statement that it was powerless to do anything further than to make a recommendation; that they had no power to act, or to compel the railroads to take action.

That a condition exists that is grossly unfair to the electrical interests, is realized by every manufacturer.

The only suggestion your committee has to offer is that the matter be taken up in the United States courts, and it recommends the employment of suitable counsel to this end as being the only possible remedy to-day.

We are satisfied that the conclusions of the committee will justify the submitting of the case to any competent attorney, which are that it is a clear case of unjust discrimination. If that be true, the association has every reason to take the step recommended by the committee. Necessarily, this will cost money, which we think will be forthcoming at the hands of the manufacturers, members of the association, and others.

Respectfully submitted,

Committee: { JAS. I. AYER, Chairman
GEO. W. DAVENPORT
W. C. BRYANT

THE PRESIDENT: Gentlemen, what action will you take on this report?

MR. BEAN: The suggestions contained in the report are very important, and I move that the recommendations made be referred to the executive committee.

The motion was carried.

MR. NEAL: I move that the several papers presented to this association that have not been formally accepted, be now accepted.

The motion was carried.

THE PRESIDENT: The report of the committee on standard rules will now be presented. This report is also by Captain Brophy, the chairman of the committee.

Mr. Davis read the report, as follows:

REPORT OF THE COMMITTEE ON STANDARD RULES

To the Officers and Members of the National Electric Light Association:

GENTLEMEN: Your Committee on Standard Rules has continued the same line of policy during the past year as heretofore, viz.: to discountenance any changes in the national code of rules not absolutely necessary. But with the march of improvement in the electrical field some changes therein and additions thereto have been found necessary since the issue of 1897.

Many of the changes were suggested by the chairman of your committee, and others received his approval. The policy heretofore pursued by the insurance organizations, of sweeping out of existence thousands of dollars' worth of material that had been previously used with the sanction of insurance inspectors, has been abandoned; and, while new and better devices and material are substituted, an opportunity is afforded the manufacturer, dealer, contractor, and station manager, to sell and use the material and fixtures on their hands.

The thickness of interior conduit, lined or unlined, has been established, and commercial gas pipe taken as the standard.

"Weatherproof" wire, so-called, is tabooed for interior construction, unless covered with a slow-burning material.

A standard of thickness of insulation on wire, after a conference with the manufacturers, has been established.

The much-vexed question of the proper distance between fuse terminals has been determined, as well as the distance between fuse metals of opposite polarity. Switches are now being standardized as to the proper breaking distance between poles, etc.

The rules have been changed so as to permit the running of two or more small motors in series multiple or multiple on constant-potential circuits.

Rubber insulation is not now insisted upon for flexible cord pendants in dry places, but an elastic, slow-burning material may be used.

Rule 40 has been so amended as to permit in dry places the use of a slow-burning insulation similar to what has been known in the past as "underwriters."

In future, as in the past, the interests of the association in the matter of changes in, or additions to, the rules for safe wiring will be diligently looked after. Respectfully submitted,

Wm. Brophy, Chairman.

The President: This report is now before the meeting for action. Up to a short time since, no repairing could be done to any interior wiring that was put in five or six years ago under the standard in force at that time. Where any repairs or additions were necessary, the whole of the wiring had to be put in according to the present rules. As I understand from this report, the Board of Underwriters has eliminated that necessity. The wiring, though it does not meet the requirements of the present board, if put in according to the requirements of the board four or five years ago, still remains, and only additional wiring must be put in under the revised rules.

MR. BEAN: I move that the report of the committee on standard rules be received.

The motion was carried.

THE PRESIDENT: We will now have a paper by Mr. Elmer A. Sperry, of Cleveland, on "Automobiles as a Source of Revenue for Central Stations."

Mr. Sperry not being present, the paper was read by Mr. George F. Sever, and was as follows:

AUTOMOBILES AS SOURCE OF REVENUE FOR CENTRAL STATIONS

One year ago, in New York, predictions, optimistic in their general tone, were made as to the rapid and general adoption of electric road vehicles, and some disappointment has been felt by station managers that more substantial advancement toward heavy demands for current has not been forthcoming for this purpose. Managers will recall that during the year frequent inquiries have been made that have not resulted in desirable business.

It is my purpose to outline briefly some of the factors that have contributed to these unfavorable conditions, and to record some advances made.

It has been discovered in many instances that the demand for current is not as favorably located on the load curve or on the network as was hoped; for instance, electric delivery wagons required charge at times of heavy load, and on the part of the net work heavily taxed in lighting. Again, the factors controlling the seasons of the heavy demand for lighting during the year are found identical and in phase with those requiring heavy duty of commercial electric vehicles. The carriage of the shopper and delivery vans are both more active at these seasons; furthermore, the same weather conditions producing heavy traction at the same time increases the demand for light. In a word, the diversity factor that it was hoped would be introduced with the automobile has not been in evidence.

Many of these difficulties may be made to disappear entirely, and a diversity factor be developed which is practically ideal, by the simple device of duplicating the traction batteries. Where this has been done it has been found that the charging can go forward at times and rates dictated by the station and practically under its control. No hardships need be experienced by rigid conformance with this practice. Careless infringement of this principle may be remedied in a number of ways; the employment of two-rate meters has been suggested in this connection.

The station management has not in all instances been able to conceal disappointment at the unfavorable developments along some of the lines above pointed out, and has allowed it to react back to inquiring parties. I regret to say that prospective customers have in instances been embarrassed by want of co-operation, aid and enthusiasm justly expected from the management. Opportunities have thus been lost to encourage the industry as the results that are now assured amply justify, as I shall endeavor to show.

Mechanical traction is coming rapidly to the front—animal power is being superseded on every hand; and, especially for commercial uses, a universal effort is being made to break away from the horse and place roadwork on a mechanical basis. As a source of power the mechanical is found to be simpler, more reliable, and shrouded in far less mystery, than the cellular-tissue-nerve combination. It should not be out of place, before this body, to recall some of the evident merits and advantages of the electric over other automobile systems. The perfect storage battery presents some remarkable features. It even rivals the electric motor itself in its fitness for, and special adaptability to, the automobile problem. Its very large reserve power at instant command; its entire freedom from danger when fully charged; its almost constant pressure throughout its capacity,—mark its superiority. This straight line of discharge of the battery is not matched by any other power-storage system of which we have knowledge. The recently developed capacity for quick charging, and the ease with which the charge may be obtained in almost any hamlet in the country, are among its advantages.

It has long been supposed that compressed air is an ideal form of stored power, but it is safe to say that electric storage distances compressed air in all the important features. Reliable batteries are now available, and on the market, that will yield for each hundred pounds 1.8 horse-power hours. Compressed air will yield to every hundred pounds (air and tank exclusive of reheater) three horse-power hours; or six times the power for electric that it is possible to obtain from air. This result will be a surprise to some engineers. The fact that with the electric system we have a rotary motor of ideal simplicity, with a capacity for overload coupled with an efficiency that is nothing short of wonderful, contributes inestimably to the success of electric-motor-driven systems, and is in marked contrast to the multiplicity of compounded, reciprocating engines employed as motors by our compressed air friends.

The single feature of constantly increasing cost of supply of fuel-using vehicles has already driven the makers to the extremity of seriously considering alcohol, with its weak power factor, as a possible substitute for the lighter petroleum products. The thoughtful engineer is constantly confronted by conditions indicating that in the realm of power coal is king, and only those traction systems that are organized to derive power from this source will keep to the front. This point, coupled with the electric system, is responsible for the stupendous development in present urban or street traffic; to show its superiority over all other powers, one needs only to recall the total absence of either steam or gasolene street cars; germane to this subject, the question is often asked, Will autos replace street cars? Its great flexibility and independence of track certainly render the new claimant an ideal urban conveyance. Can the central-station man look forward to supplying so large a demand as would thus be created?

The automobile under street-car conditions brings forward an interesting field of inquiry. The single fact that the stupendous cost of permanent way and its maintenance is at once eliminated, makes the problem of more than ordinary importance. The interest and income on these two items would yield so large a sum as easily to offset much extra expense of operation, and especially expense attending the development and smoothing out of the early workings, and covering the expense of adjusting a system of this magnitude to new conditions. Such a system would, however, be subject to certain limitations, chief among which will be found increased weight per passenger, difficulty of easily directing the excessively heavy structure, large increase in power per passenger carried, increased rolling-friction factor, and, one of the most important, the limitation as to road-bed, soft tires being precluded by the excessive tonnage. Considering these factors separately and collectively, the point is at once reached, showing conclusively that with anything like wheel pressures equal to that now obtaining in street-railway service, nothing but steel pavement could be practically employed. To demonstrate this matter, tests were made as follows: Asphalt road-bed was taken as the standard road-bed of the future. A piece of very hard asphaltum, laid in the most approved manner and in constant use for two years, was selected. This had been maintained at an average temperature of thirty-eight degrees for eighteen hours (no sun), highest temperature during the time being forty-six degrees at time of test. A sixty-two-inch wheel with three and one-half-inch steel tire was loaded to 5,000 pounds on scale. This wheel was taken over various parts of the hard asphaltum, with the following results: Once over, average depression, .029 inch: twice over, average depression, .047 inch. These depths were taken by a micrometer, depth guage easily reading to one-fifth of a thousandth of an inch, and some thirty readings were taken in each instance. It will be noticed that this depression is somewhat over one and one-half thirty-seconds of an inch. The amount of this depression is surprising, considering the comparatively light load, broad tire, large wheel, extremely firm condition of the road-bed, and the temperature at which the asphaltum was tested, and seems to bear out the statement that the real limitations to the proposition are probably more those of road-bed than of any other one factor.

Another factor destined to increase greatly the radius action of electric vehicles, and the consequent demand for power, is roadway improvement. The present good-roads agitation is certainly in line of progress, and should be given every encouragement and aid possible. In this connection, I see no reason why we could not wisely follow the plan based on historical precedent, and utilize for this important work of permanent improvement our convict labor, the disposition of which in this country has always been a source of embarrassment to the authorities This system certainly has much to recommend it, and the improvement of our roadways calls for a vast expenditure of labor and has much need of a uniform and systematic effort.

The fact remains, and has been emphasized within the past year, that progress in electric vehicles has not been as rapid as was expected, and causes must have existed that were not before seen and were not in general understood. Some vital reason seems to have prevented the rapid development and general adoption that seemed at one time assured. Is it the element of cost? Two important conditions stand out prominently in connection with electric road vehicles: these are, first cost and cost per mile of operation. It is not my purpose to discuss the first, as there are endless variables entering into the question, and it is doubtless true that the prices will gradually decrease. This part of the problem is always found to be self-correcting, and even to-day, with the electric, the cost per pound of vehicle complete is lower than other and far less available and pleasurable systems.

The cost of electric power for automobiles has been demonstrated in Paris to be less than that of any other power system, and surely this factor is not the one now preventing wide adoption of electric vehicles. In a paper before the American Institute of Electrical Engineers, G. F. Sever and R. A. Fliess, of Columbia University, give results of extended. trials with electric delivery service in New York city. It is shown that with present power and rolling-friction factors, there is effected a saving of nearly two and one-half cents per car mile over horse service, and with the capacity of many more miles per day than with horses. With a daily service of thirty-six miles, a saving of 356 hours per year of actual delivery service per vehicle is effected. The average horse was found to have a capacity for three hours' work per day at the rate of seven miles per hour. The authors state: "The figures given above speak for themselves, and would appear to be most effective argument in favor of adopting electric automobile delivery service."

A popular notion exists that carriage batteries and electric carriages are charged with a certain number of miles. It requires only a second thought to see the error and delusion embodied in this idea. It is evident that a battery when fully charged contains, not miles, but electrical power, which may be expressed in horse power, and which is proportional to the size and capacity of the particular battery in question. With this in mind, it will be readily seen that the statement that a carriage contains a capacity to run a given number of miles would only be true when a certain standard pavement or road-bed be considered; because it is found that it requires very much more battery power to drive a carriage a mile or more on soft, uneven and hilly roads than it does on smooth, hard and level roads. It should always be understood that a standard pavement or road-bed is considered.

Again, for instance, where two motors are employed the power and efficiency is divided, requiring, it is found, a larger amount of power from the battery to drive a vehicle of given weight a mile upon standard road; again, the mechanical condition of the bearings or amount of rolling friction present in carriages of different makes also varies. It is evident, therefore, that a number of important considerations should be included in any attempt to give a definite or prescribed mileage capacity to electric vehicles and their batteries.

In electric-road traction, the consideration of prime importance is the battery. What is its efficiency, its durability, and, above all, at what cost will it produce a ton mile.

We will confine our attention in the following remarks to that class of storage battery known as the lead-lead element. These batteries are of two general kinds; the one having its active material formed or developed from metallic lead—Planté's process; the other having its active material mechanically applied, —the Brush or Faure process.

A prominent German writer, giving results of recent tests, states that an average carriage with a Planté battery would run twenty miles per charge, the battery weighing 1,260 pounds, yielding 2.8 ampere hours per pound, 5.25 watt hours per pound, and requiring fifty-one pounds of battery per ton mile; whereas, with the Faure battery of the same capacity, he found the weight to be 980 pounds, yielding 3.6 ampere hours per pound, 6.5 watt hours per pound; running the same carriages, an average of twenty-nine miles requires thirty pounds of battery per ton mile, showing a life of 3,000 and 4,000 ton miles.

This simple report reveals the fact that batteries of different weights, though possessing the same capacity, will propel the same vehicle different distances, requiring a marked difference in the pounds of battery per ton mile. One of the highest engineering authorities in storage batteries recently stated:

"The advantage which would follow the introduction of a high-capacity cell would not be merely the extension of the radius of action of the electrical vehicle, but would be a lengthening in the life of the battery itself. This is brought about by the fact that it would almost entirely remove the most powerful cause for deterioration,—that of overdischarge. Present batteries have twenty to thirty miles capacity. In the case of a battery capable of propelling a vehicle sixty miles on one charge, only the most inexcusable carelessness could bring it to the state of complete discharge, for ninety per cent of the discharges would be for distances of less than thirty miles. Under these circumstances the battery would be seldom discharged over fifty per cent of its capacity, a condition of affairs which would insure a greatly increased life, probably between four and six times the life under present conditions."

The importance of proper manipulation, also proper adjustment of the capacities to the work to be performed is here emphasized. Not only will it be seen that the life of the battery is improved, but, what is more important, the cost per ton mile is also materially reduced. In this connection, it will be interesting to investigate the relation of the cost of operation per mile due to this factor, namely, the storage battery. Very little if any literature is available on this all-important subject, and, in fact, so little experience up to the present time has been available, and so little information has been given out, that it is not surprising that only meagre records of this function exist.

Beginning with the supposition that the present heavy batteries, namely, those yielding about two and three-fourth sampere hours per pound, are possessed of a given life, certain deductions will be made by introducing series of variables yielding results and data, the bearing and significance of which is of more than passing interest.

Before entering on a more detailed discussion, it might be well to state the result of more general observations in this line. The desirability of the electrical system of traction, the extent of its adoption, and consequent extent of the demand of the central station for supply, will depend upon the earning capacity that can be demonstrated. The value and present cost of the same work are both known factors. The question remains, what is its cost under the new conditions? Under practical conditions of operation a battery having a life equal to 1,000 ton miles will drive a vehicle weighing a ton 1,000 miles, or a vehicle weighing two tons, 500 miles. For purposes of illustration of the possible cost of this factor, let us assume that this battery costs $500. It will then be seen that each cab mile covered in the latter instance will cost one dollar, which would, of course, be prohibitive. Nevertheless, it is a fact that batteries have been made and marketed, and, what is still more serious, others have been so misused in practice as to have a life less than above assumed. Suppose the average life of the battery to be five times that assumed: The new cost per cab mile will be twenty cents.

In the early stages of any industry, conditions are often found to exist, the practical results of which, though startlingly disappointing, are finally met and overcome; and especially is this true where the result is an important one, and where capital and skill are available. This is most certainly true of the art under consideration, and within the past year advances have been made that are favorable in the extreme; advances that are destined to reverse the adverse verdict, and place the art of electric-road traction by batteries high above possible criticism.

Taking unity as a basis of the battery factor in the cost per mile, we will proceed to introduce the variables as to weight and cost, and note the results.

Suppose we assume that the heavy battery is about half the total weight carried. Engineer Maxim, in his Milwaukee paper, says forty-five per cent. This is close enough to fifty per cent for present purposes.

First, assuming a battery of same capacity to weigh one-half. It will at once be noted that the vehicles carrying battery of only one-half the present weight can be made easily one-eighth lighter, giving a total reduction of weight of one-fourth plus one-eighth, or three-eighths. The capacity remaining the same, the lighter combination, or new carriage, will be propelled unity divided by .625, or 1.6 times its former mileage. This factor, 1.6, represents the new mileage, yielding the new cost per mile of five-eighths (.625).

In the above calculation it has been assumed that the lighter battery costs the same as the heavier battery, or twice the cost per pound.

Light battery costing the same per pound as heavy battery, the cost now is reduced to one-half, but the battery is of the same capacity, and will propel the vehicle 1.6 times its former mileage. Introducing this factor we have a new cost per mile of less than one-third (.31).

Important reductions in cost per pound of battery have been made within the past year. Let us now assume the following:

Light battery costing one-half per pound of the heavier battery, the cost becomes one-half of one-half, or one-fourth; but we still must introduce the mileage factor of 1.6, which yields 1.5, or a cost per mile of one-seventh (.155).

In the above calculations we have assumed only the original life of the batteries, with no renewals. It is found in practice that with vehicle batteries the renewals cost about one-half the first cost of battery, and the life by renewing is extended half the former period; a condition, it will be observed, that does not alter the cost factor per mile.

It has been found that a battery when exhausted weighs as much, and is possessed of its full quota of chemical lead, and though heretofore it has been difficult to recover any portion of its original cost, at present, with the batteries of one maker at least, it is possible to recover and re-use the exhausted material over and over again at slight additional cost, the original total investment in lead being practically the only investment required.

Assuming now that these renewals be made at half original cost, and that the batteries be carried through only four such renewals, it is found that the whole battery cost and energy produced throughout its extended life is six-tenths of that during the first period, which alone has been considered above. Introducing this factor in the last result we find a cost per mile of practically one-eleventh (.094).

Advances in the art have, however, gone further than reducing the weight of battery by one-half, and it is now possible to obtain in the market batteries of excellent life that have the original capacity with one-third the weight. With such a battery, a vehicle required to carry one-third weight of battery can easily be made one-sixth lighter, making a total reduction of the combined weight of one-third plus one-sixth, or one-half. This battery, having the same capacity, will push the lighter vehicle a distance of unity divided by .5, or twice the mileage possible with the heavy battery, or at a rate of cost per mile of one-half (.5).

The last result assumes that the light battery (one-third weight) costs the same as the heavy battery.

Light battery costing same per pound as heavy battery, the weight being only one-third the cost, will, therefore, at once be one-third. But it will still drive the carriage twice the mileage, yielding a total cost per mile of one-sixth (.166).

Light battery costing one-half per pound, there being one-third the weight, the cost will at once be one-sixth, the battery, still having the original capacity, will propel the carriage twice the mileage, as above, and will yield a total cost per mile of one-twelfth (.0833).

Carrying this battery through a course of four renewals under the conditions above stated with reference to renewals, we find that through the extended life of the battery the cost per mile has been .0833 x .6 = .05.

The realization of these sweeping reductions in cost is all-important. The results are evidenced as follows: Vehicles with live load, total weight of one and one-third tons, have yielded 1,000 miles per discharge with batteries weighing less than 1,000 pounds. Partial realization of the desirable features yielding the results above given, will work economies that are proportionate. The above calculations are given not only as indicating the high point that has been attained in the development of traction batteries, but also as indicating the line in which future effort should be directed for still further advancement.

As showing the position of this country in this most important work, and especially the recent developments and advances made on this side, reference will be made to the competitive tests recently concluded in Berlin in connection with the International Motor Car Exhibition in that city, which were productive of important and valuable data upon electric motor vehicles. Not the least interesting is the average weight of battery to the ton mile. This figure is named as twenty-eight pounds per ton mile, but calculation shows it to be nearer thirty pounds.

It will be seen in the test recorded from the German authority quoted earlier in the paper, that the values of thirty and fifty-one pounds per ton mile were assigned. Values in this country for vehicles most frequently range between twenty-eight and fifty pounds. As the result of experience, the author would state that this value should be held to or below ten, and vehicles that can easily show this value are in daily commercial service, which makes an extremely favorable showing. So light a battery lends itself readily to the duplication of batteries referred to as creating the necessary diversity factor. The results of the battery tests, so-called, made under the auspices of the Automobile Club of France, recently concluded, indicate that the best results must be expected from batteries in which the active material is retained, or its retention in place upon the grid is materially aided, by the use of proper envelopes, this being especially true with traction batteries. Furthermore, every means should be employed to shield the battery and thoroughly insulate the same, not only electrically, but especially against jar and vibration. It has been demonstrated that concussion and molecular vibration are factors tending most seriously to disintegrate the elements.

A plan has been devised that seems destined to secure this result; it affords a cushion support for the individual plates by the simple device of rendering the cap of the plate supports within the receptacle elastic and yielding, thus allowing it to perform the function of a cushion.

As a result of the past five years' observation and close contact with this most engrossing work, the author can assure station managers that the time has arrived when traction batteries, under conditions of vehicular traffic, are making excellent records and showing commercial results that are most satisfactory. At last this element of greatest mystery and uncertainty, and the one that has beclouded the electric-vehicle world from the first, has cleared from the horizon, leaving only known factors with which we may deal with certainty. The success of the electric-vehicle being thus assured, a steadily increasing demand for current is sure to follow, which will result in large business. This field belongs to the central station by right of discovery; but history repeats itself, and the opportunity will be lost if the territory is not occupied and its resources developed. The central-station organization and equipment is the proper guardian and natural source of expert service and attendance for both battery and machinery, and will naturally be looked to to foster the interests that it shares with the vehicle operators. It has not been demonstrated that central-station owners should not be the principal operators themselves. Much can be said in favor of such a combination. In any event, they should closely ally themselves with this important industry, and the earlier a practical experience is had by the station men themselves, the sooner will they understand the needs of the business and be prepared to guide their patrons into a successful and widespread use of electric road-traction.

THE PRESIDENT: The paper is before you, gentlemen, for action.

MR. BEAN: I move that the paper be spread upon the minutes, and the thanks of the association be extended to Mr. Sperry and Mr. Sever.

The motion was carried.

THE PRESIDENT: Gentlemen, if there is no discussion on this paper, we will hear Mr. Feicht, of Pittsburg, read his paper on "Combination Electric Lighting, Power and Railway Work."

Mr. Feicht read the following paper:

COMBINATION OF ELECTRIC LIGHTING POWER AND RAILWAY WORK.

The more general introduction of electricity for lighting, power and railway work, has given rise to a tendency to combine these different kinds of service and centralize the generating stations. The tendency has been most marked in electrical work during the last two years. In fact, if one were called upon to name the most important phase of electrical engineering of to-day, he would undoubtedly instance the development of central stations for supplying current for the various branches of electric lighting and power service.

During recent years, the superiority of the electric over all other systems of traction for street and suburban railways, has been demonstrated by thousands of practical plants operating in all parts of the world.

For power purposes in mills, factories, and shops, electric motors are rapidly gaining ground in supplanting steam engines with shaft and rope transmission. Electric lighting has become an essential part of all modern residences, business buildings, factories and mills..

By combining the various branches of electric service, a far more efficient utilization of the generating plant can be effected. The advantages of one large central station over several small ones of the same total capacity are : first, larger units can be used, which will have a higher efficiency and a better regulation; second, the fluctuations in the load on the generators will be less pronounced, and therefore the service rendered will be more uniform; third, the first cost and the operating expenses will be less.

There are three general classes of combination electric plants: that in which alternating-current generators are used and direct-current service is operated through rotaries; that in which direct-current generators are used and alternating-current service is operated through rotaries; and that in which double-current generators are used for both classes of service. It will be the object of this paper to consider some of the more important questions involved in the construction of such plants, principally those of the alternating type, since it is the prevailing one on account of its flexibility and adaptability for transmission purposes.

ALTERNATING-CURRENT COMBINATION PLANTS

In designing an alternating-current combination plant, there are a multitude of questions presented to the electrical engineer. The location of the station must be decided upon; the size and type of generator best adapted for the service; the frequency, voltage, etc.; all of which are more or less interdependent. These questions often involve the solution of most difficult problems, depending not only on the present demands of the service, but on the future growth of each branch of the service.

The size of generator to be used will depend upon the total capacity of the plant. The advantages of large units over small ones of the same aggregate capacity are, briefly stated, increased efficiency and regulation and decreased first cost, floor space, and attendance. The general practice shows a steady growth in the size of generating units. Looking at the question from the standpoint of economy in repairs for both generators and engines, the units should, if possible, be duplicates. Where the capacity of the plant will probably not be increased for a considerable length of time, the size of the units may be smaller than where additions to the plant in the near future are anticipated. Where, however, it is the intention to make early additions, it may be advisable to install generators commensurate with the ultimate capacity of the plant.

Whether the generators are to be belted or direct-connected, is the second question to be decided. In general, the belted generator running at a higher speed than the direct-connected generator of the same capacity will weigh less, and consequently cost less, than the latter machine. Were the first cost the only consideration, direct-connected generators of sizes less than about 1,000 kilowatts would not be used to any great extent. There are, however, other considerations besides first cost, in view of which direct-connected machines have decided advantages over belted machines. When the capacity of a plant is small and not located in a thickly populated district where noise is objectionable and real estate high, the belted machine will find favor. But for large stations where compactness and noiseless operation is desired, the direct-connected generator must be used.

The type of generator to be selected will depend primarily on the voltage of the system. The three general types are: revolving armature generators, revolving field generators, and inductor generators. In the machine with a revolving armature the electromotive force is generated in the moving wires and the current is taken off through collectors or slip rings by means of contact brushes, usually made of copper. For electro-motive force of 3,000 volts or higher, this type of machine is not well adapted. For such voltages the armature coils are usually wire wound, and must of necessity be heavily insulated, which makes the construction unsuitable for withstanding the mechanical stresses to which they are subjected. Again, the collector rings are not well adapted for high voltages, as they are unprotected and require some little care, which, on account of the danger involved, they are not likely to receive.

For low voltages bar windings can be used. With this type of winding the conductors are held in place in the slots by the overhanging tips of the armature teeth, or by supporting wedges, and the whole forms a most perfect mechanical construction, which it is practically impossible to injure at any reasonable speed. In general, for low voltages, the revolving-armature machine of a given weight can be made slightly more efficient than other types. The difference in efficiency may sometimes amount to one per cent at full load and considerably more at lighter loads. This is due to the fact that the windage of the revolving field is greater than that of the revolving armature, and the iron loss in the armature of the revolving-field machine is greater than in the revolving armature.

In the machine with a revolving field the electro-motive force is generated in the wires in the stationary element, and the current is taken off through protected terminals attached to the generator frame.

The low-voltage exciter current is introduced into the field coils through collectors by means of copper or carbon brushes. This type of machine is admirably adapted for high voltages, as the armature coils are not subjected to any mechanical stresses and may therefore be designed with special reference to high insulating qualities. It is almost needless to say that this type of machine may also be used for low voltages, but its lower efficiency will in many cases restrict its use for this class of service.

The advantages claimed for the inductor type of machine for high voltages is that it has no moving wires or collectors. When compared with the old surface-wound machines with band wires, this advantage is apparent, but when compared with the present type of the revolving-field machine, it becomes insignificant. For durability, the latter machine cannot be excelled. Its revolving element is practically as firm in its construction as a boiler-plate fly wheel. It is true that the revolving field machine has collector rings which require some little attention. This disadvantage, however, is outweighed by the fact that on account of poorer regulation the inductor generator will require much more attention at the switchboard. The inductor generator is inherently a poor regulating machine. For a given weight its regulation will not compare with that of other types. In order partially to overcome this defect, the inductor generator must be made larger than other types, and the iron must be worked at a higher induction, which results in a lower efficiency. The inductor generator has also other serious disadvantages, resulting from its stray magnetic field. In nearly every case where such a machine is direct-connected to an engine, special precautions must be taken to prevent this field affecting the governor mechanism and thereby interfering with the speed regulation of the engine. In some instances there is placed on the outside of the inductor, encircling the shaft, a large coil through which the exciting current is run to neutralize the stray field. In other instances parts of the governing mechanism are made of brass or of some other non-magnetic materials. Besides affecting the speed regulation, this stray field sets up an electromotive force in parts of the bearings, the resulting flow of current pitting the babbitt and causing it to wear away rapidly.

We will next consider the electromotive force of the generating units. The voltages for which alternating-current generators are usually built, range from 220 to 6,600. Machines for lower electromotive forces may be readily made, but, on account of their relatively high current per kilowatt, there is little demand for them. For voltages higher than about 6,600, generators can not be built as economically as for lower voltages. The severe electrical stresses in such machines make the problem of insulation very difficult. The coils require a proportionally larger amount of insulating material than those of lower-voltage machines. This necessitates relatively larger armature slots and consequently larger machines. The difficulty encountered and the danger involved in handling high-voltage currents at switchboards, are also points in favor of low voltages. Unless the conditions are exceptional, it will be found advisable to use a voltage between the limits of 220 and 6,600.

Where a large portion of the output of the plant is to be transmitted at a high voltage, say about 10,000, transformers will be needed, and a comparatively low-voltage generator may be used, the voltage being adapted to some other branch of the electrical service. If 550-volt rotaries are operated in the station for railway work, 340-volt three-phase, or 390-volt two-phase, generators may be used to advantage, as the rotaries may then be connected direct to the 'bus-bars. If, however, the railway service is comparatively small, it will not always be advisable to use such low-voltage machines, on account of the extra heavy leads and switchboard apparatus that will be required for handling the current before stepping up for transmission. For feeding lighting circuits adjacent to the station, a 1,100 or 2,200-volt system would fill the requirements very well.

Where a large portion of the output of the plant is to be transmitted at a voltage not exceeding 6,600, the selection of generators capable of delivering this electro-motive force direct, will avoid the cost of one set of transformers. As an illustration of the selection of low-voltage generators for combined power and lighting service, the plant of the Independent Electric Company in San Francisco furnishes a good example. This plant will consist of 1,500-kilowatt, two-phase, 7,200-alternation, 500-volt, direct-connected generators. The use of 500 volts in this case permits power to be furnished direct from the generators for alternating-current motors. Were 1,000 or 2,000 volts used instead of 500, lighting circuits could be operated direct from the generators, but the motor service would require the use of step-down transformers. The more important of the two services decided the selection of the low voltage.

The plant of the Snoqualmie Falls Power Company is a good illustration of the choice of an intermediate voltage for lighting and power work. This plant consists of 1,500-kilowatt, three-phase, 7,200-alternation, 1,000-volt generators, direct-connected to water-wheels. For transmission to Seattle and Tacoma, the voltage is stepped up to 15,000 or 30,000, as desired. The adoption of 1,000 volts for the generators was made with the view of securing reasonable safety in handling the current, and, at the same time, of avoiding the use of extra heavy leads and cumbersome switchboard apparatus, which would be necessary with a low voltage.

An example of high-voltage generators for combination service is furnished by the plant of the Kings County Electric Light and Power Company, of Brooklyn. In this plant 6,600-volt generators are used, which permit of transmission direct to the distributing centres, without the intervention of transformers.

The proper selection of the frequency for a combination alternating-current plant is one of the most difficult problems. The choice is usually made between a frequency of sixty cycles per second, which is the standard for lighting plants, and a low frequency, usually twenty-five cycles. Each one is best adapted for particular class of service, and, therefore, when a plant combines a number of different kinds of service, that frequency must be chosen which will give the best average results. Where a frequency of twenty-five cycles per second is adopted, slow or moderate-speed generators will give the best results. High-speed generators must of necessity have a very small number of poles, which makes their performance poorer than that of slower-speed machines. Twenty-five cycle transformers are somewhat larger and more costly than those for sixty cycles. Their performance, however, is about the same as for the higher frequencies. Transmission at twenty-five cycles is slightly more economical than at sixty cycles, as the inductive drop in the lines is less. This, however, is of little importance, excepting where the transmission lines are very long or the current in the line very heavy. For slow or moderate-speed motors, twenty-five cycles is very well adapted, as it permits the use of motors without an abnormal number of poles. Their performances are usually very good, but on account of their speed they are somewhat larger than the standard motors of the same capacity for higher alternations. This frequency is not well adapted for high speeds, on account of the extremely small number of poles required. The highest speed possible is 1,500 revolutions per minute for a two-pole machine, which is of necessity a poor design. The smallest number of poles sanctioned by good practice is four, which gives a maximum speed of 750 revolutions per minute. This speed is low for motors under seventy-five horse-power capacity.

Rotaries for voltages ranging from 500 to 700 operate very satisfactorily on twenty-five-cycle circuits. Such machines have a comparatively small number of poles, and run at moderate speeds, both of which are favorable conditions for high voltages. The performances are in general equal to those of the best direct-current machines. For low-voltage rotaries this frequency is not always as suitable as the higher frequencies. For a given output, a reduction in voltage necessitates a proportional increase in brush capacity. This can be obtained only by lengthening the commutator or increasing the number of poles, which means reducing the speed. Both methods result in increasing the size of the rotary.

Incandescent lighting on twenty-five-cycle circuits is, in some cases, not entirely satisfactory. The slight "winking" of the lamps at this frequency which sometimes occurs, restricts the use of twenty-five cycles for commercial lighting. For factory or series street lighting, where the service is not so exacting, this frequency may be used. The variation in the brilliancy of the lights depends upon the wave form of the current. At Niagara Falls the twenty-five-cycle current from the 5,000-horse-power generators is said to give perfectly satisfactory lighting.

Arc lamps will not operate satisfactorily on twenty-five-cycle circuits, as the low frequency causes a very objectionable "flicker" in the lights. The most common method of operating arc and incandescent lamps for twenty-five-cycle circuits is by the use of motor generators. These outfits usually consist of induction motors belted or direct-connected to higher alternation generators, or to direct-current series arc machines. This system is in successful operation in quite a number of plants at the present time. Synchronous motors may be used in place of induction motors, but they will not usually give as good results. The synchronous motor is one of those machines that are subject to "pumping" or "hunting," when there is any pulsating tendency in the system. This pumping action may cause the lamps on the generators driven by the motors to "wink" or "flicker," and may be as objectionable as the original difficulty which the motor generator was designed to overcome On the other hand, when there is a pumping tendency in the system, the induction motor will not follow the pulsations, but will oppose them. In this action it serves as a damper in the system, and thereby materially improves the operation of any rotaries or synchronous motors that may be on the same circuits.

What has been said of twenty-five-cycle circuits, applies equally well to thirty-cycle circuits, excepting that incandescent lamps are not liable to flicker, on account of the frequency. Sixty cycles per second is the standard frequency throughout the United States. This is, in general, very well adapted for all classes of service.

For high-speed generators (often required in connection with water-wheels), this periodicity is better adapted than lower ones, as it permits a larger number of poles for a given speed. The regulation is in general better than for the lower frequencies, the efficiency being practically the same. Very low-speed generators may be made for this frequency, but the large number of poles usually renders the construction more difficult than for the lower frequencies. For moderate speeds the construction is less difficult and the performances are usually the same as for generators of similar size and lower frequencies.

Transformers for sixty cycles will be smaller than for twenty-five cycles. The extreme difference may vary from twenty to forty per cent. The efficiencies will be about as high as for the lower frequencies. Transmission at sixty cycles will be slightly less efficient than at twenty-five cycles, on account of the higher inductive drop.

Very low-speed motors are not well adapted for sixty-cycle circuits, as they have a relatively large number of poles, which results in either poor performance or abnormally large proportions. For moderate and high speeds, the number of poles is smaller and the performances better.

The limiting voltage for 7200-alternation rotaries, is about 600. This is due to the fact that, for a given speed, the number of poles is greater than at lower frequencies, and, therefore, the distance between brush holders relatively less. For lower voltages this frequency is admirably adapted, as the large number of brush arms makes the handling of heavy currents an easy matter. The performance of such machines is practically as good as for low frequencies.

Both arc and incandescent lamps operate satisfactorily on sixty-cycle circuits. The power factor of constant-potential arc-lamp circuits varies from seventy to eighty per cent, and that of series arc-lamp circuits, from seventy to ninety per cent. When this is considered objectionable, a motor-generator may be used to advantage. Large induction motors for such service will have a power factor at full rated load of from ninety-one to ninety-four per cent, and on account of the relatively lower starting torque required, the efficiencies will also be very high.

DISTRIBUTION

The method of distribution from the alternating-current generators to the points of application of the electric current are quite varied. The simplest system consists of separate generators, feeding independent circuits for particular lines of service. Such a system is necessary when the fluctuations in power are so great as to render lighting from the same generators unsatisfactory. The plant of the Snoqualmie Falls Power Company furnishes a good illustration of this system. The switchboard at the generating station is equipped with double sets of 'bus-bars and double-throw switches, and is connected with the distributing station in Seattle through two separate transmission lines, thus making it possible to run any number of generators for either separate or combined service.

When the fluctuations in the power service are less violent, but still sufficient to affect lighting service on the same circuits, the most common arrangement is to have one or more generators feeding a common 'bus-bar, from which separate circuits are run for the different branches of the service. This is preferable to the former arrangement, as it permits the operation of all the generators in parallel, thus increasing the overload capacity of the plant and making it possible to work the generators nearer their normal rating, at which point the regulation is best and efficiency highest.

At the present time the paralleling of properly-designed direct-connected alternators is as simple as the paralleling of direct-current machines. Successful multiple operation does not depend upon the type of generator, the number of its phases, its voltage or frequency, but upon its regulation and electrical characteristics, upon the uniformity of its angular speed or the regulation of its prime mover, or upon some combination of these; it being, of course, assumed that the generating units have the same general characteristics. The ideal conditions, which will always give satisfactory results, are: First, good generator regulation. Second, uniform angular velocity. Third, speed regulation over a range of approximately four per cent from no load to full load. Good voltage regulation of a generator implies a low self-induction in the armature, and consequently an easy path for the flow of corrective currents, when for any reason the armatures are not exactly in step with each other.

The conditions necessary for the parallel operation of belted generators are less rigid than for direct-connected machines. The natural tendency of armatures when in multiple, is to keep in step. The "give" and "take" of the belts permit them to do this much more readily than when they are direct-connected.

A third system of distribution, which may be used when the fluctuations in the power service are not sufficient to interfere with lighting on the same line, consists of common feeders for both light and power service running from common 'bus-bars. This system is largely adopted on account of its simplicity. It should not be used where the power is a relatively large percentage of the output of the plant, excepting where the load is comparatively steady and the majority of the motors are started but once or twice a day. After a motor is started, the variations in the load will affect the electromotive force of the circuit only in proportion to the line drop. Although the power factor may vary over a wide range with the load, the lagging element of the current which affects the generator regulation will remain practically constant.

When induction motors for intermittent service, such as elevator or crane work, are operated from the same feeders that supply lights, their starting will be found to cause the least disturbance if their transformers are independent of the lighting transformers, as the maximum drop in the electromotive force is in the secondary circuits. For starting induction motors of the type that have a constant secondary resistance, for elevator and intermittent service, auto-transformers are employed, provided with loops for obtaining several low voltages, which are applied successively to the motor with a minimum effect on the line. There are cases, however, where the system of separate motor-transformers has been adopted, and has worked so satisfactorily that starting devices were not necessary.

A fourth system of distribution, which is now becoming very general, consists in running common feeders from common generator 'bus-bars to substations, where distribution is effected either directly or after one or more transformations. This system is advantageous, as it allows the main station to be located where real estate is relatively cheap, or where there are water and coal facilities, or where power from a waterfall is available. It also permits the sub-stations to be placed in the centres of the distributing districts, thus enabling the low-tension service lines to be operated with a maximum efficiency.

There are quite a number of practicable systems by which distribution can be effected from sub-stations. Speaking generally, the same conditions that allow lighting and power service on common feeders, or that require separate feeders for the lamps and motors when operated direct from the generating plant, will hold good for the same systems of distribution from the sub-stations.

The simplest sub-station, and the ideal one for distribution from the centre of a thickly populated district, where noise and vibration are objectionable, contains no moving machinery. Such a station will be capable of supplying alternating current only. It may be equipped simply with a switchboard, to which the high-tension transmission circuits are connected and from which the various feeders run, either to lowering transformers for low-tension service, or direct to high-tension motors or series arc lamps. If the high-tension switching apparatus is objectionable, the transmission circuits may first be stepped down to a lower potential before being connected to the switchboard. Provided the frequency permits, there may be operated from these sub-stations high and low-tension induction and synchronous motors and constant-current series, and constant-potential, arc and incandescent lamps. When direct-current circuits are to be supplied from the sub-station, a motor generator or rotary converter will be used, as there is at the present time no alternating-current rectifier sufficiently developed for this class of service. In addition to the alternating-current circuits previously mentioned, the station will be capable of feeding direct-current circuits for lighting, railway or commercial power service, at any electromotive force up to 550 or 700 volts, depending upon the frequency of the generators.

Under some conditions, a storage battery outfit may be found a very useful addition to a sub-station where rotaries are used. This is particularly true when the maximum output of the sub-station is greater than the maximum available power behind the rotaries. In such cases the rotaries may be used to charge the batteries during the periods of light loads, and they in turn may be thrown in service to assist the rotaries when the load exceeds their output. Storage batteries used for this purpose act as a fly-wheel to the system, by storing up energy when the supply exceeds the demand, and giving it out again when these conditions are reversed. It is probable that under other circumstances the battery can be advantageously replaced by rotaries. Storage batteries are, at best, comparatively inefficient, and are only of use in the sub-station in conjunction with rotaries or some other source of direct-current supply.

When the frequency of the generating station is lower than that required for the successful operation of arc and incandescent lamps, the motor generator will be a necessary adjunct to the sub-station for such classes of service. As previously stated, these outfits consist usually of synchronous or induction motors, belted or direct-connected to direct-current machines or high-alternation generators. In addition to their use as a frequency changer they are particularly well adapted for obtaining a constant electromotive force from a circuit on which the electromotive force fluctuates, as both types of motors will run at practically synchronous speed, independently of the voltage, provided this does not vary over too wide a range. The synchronous motor, as its name implies, must be run at synchronous speed. The induction or non-synchronous motor must be run below synchronous speed. This difference or drop below synchronism, usually called "slip," depends upon the load it carries. For motor-generator outfits the slip is usually about three per cent or less for full load and normal voltage. For a variation of ten per cent in electromotive force the slip will change only about one-half of one per cent, so that for all practical purposes the speed may be considered constant for a constant frequency. The only variation in the speed of the generator will therefore be that due to variations in the frequency of the supply circuits, which will be dependent upon the speed of the generators.

DIRECT-CURRENT COMBINATION PLANTS

The direct-current combination plant is not so generally used as the alternating plant. This is due chiefly to the fact that electric service usually involves the transmission of power to points at such a distance from the station that direct current cannot be economically used.

The same considerations which decide the selection of a generator of a given type and capacity for an alternating plant will hold good for a direct-current plant. The electromotive force at which a direct-current generator can be successfully operated, is limited to about 700 volts—the highest that can be safely commutated.

When the greater part of the output of a plant is used for the supply of lighting and power circuits in the district surrounding the station, 110 or 220-volt generators are commonly found. From such a station alternating current for more distance service may be obtained by the introduction of the static and reversed rotary converter. As such a combination will deliver alternating current at any standard electromotive force and frequency, all classes of service may be fed from this system.

Where a plant is constructed primarily for the supply of railway circuits, it is the common practice to use 500 to 600-volt generators. These will permit of economical service at a distance of five or six miles from the station. For longer distances, such as are met with on surburban roads, the rotary converter may be used. At the station these converters will deliver three-phase current at a voltage ranging from 310 to 370, and at any frequency desired. This may be stepped up to any convenient voltage for transmission to sub-stations where similar static and rotary converters will transform it back to direct current at the original voltage for motor service.

When it is desired to supply alternating-current lighting and power circuits from such plants, the rotary converter may also be used, provided the voltage of the generators is sufficiently constant. This is not usually the case excepting in very large stations. In considering the alternating-current plants, we found that where the electromotive force varied over too wide a range for commercial lighting, the motor generator was used for operating lighting circuits. We have the counterpart of this outfit for the same conditions in direct-current plants. It consists of a shunt motor with unsaturated fields, belted, or direct-connected to a direct-current generator or alternator. A properly-designed shunt motor for such service will give a very close speed regulation for variations as great as twenty per cent in the electromotive force of the supply circuits.

Direct-current lighting and power circuits may be operated from high-vóltage, direct-current stations by the use of storage batteries. In England this combination is quite frequently found. At the present time the Manchester Corporation are installing 1,800-kilowatt, direct-connected, compound generators adapted for a range in voltage from 410 to 500. These generators, in combination with storage batteries, are to be used for lighting, power and railway service. The generators are arranged for operation either as compound or shunt machines. The railway circuits are to be fed direct from the generators connected as compound machines, and the commercial lighting and power circuits, either from the storage batteries alone or from the generators connected as shunt machines in conjunction with the batteries. The power and lighting service will be fed by a three-wire system with 440 volts across the outside lines. When the generators and batteries are operated together on this system, the neutral wire will be connected to the middle point of the batteries, and the outside wires to the terminals of the generators and batteries. This system is similar to that installed a few years ago by the Imperial Electric Light, Heat and Power Company, of St. Louis.

ALTERNATING-CURRENT—DIRECT-CURRENT COMBINATION PLANTS

Combination lighting and power plants equipped with double-current generators are as yet uncommon, as the double-current generator is a comparatively recent type of machine. It is rapidly gaining favor, however, and there is now quite a decided tendency toward its use for many purposes. The chief advantage of this type of generator lies in the fact that it combines two machines in one, and may be operated at its full-load rating either as a direct-current generator or as an alternator, or as both at one time, the division of the load on the two ends being proportioned as desired. It costs considerably less than a separate direct-current and an alternating-current machine of the same capacity, and occupies practically one-half of the floor space of the two. Double-current generators may be operated in parallel on both ends. The advantage of multiple operation of direct-current machines or alternators we have already noted. By the use of double-current generators we may not only have these advantages but also that resulting from the combination of the two classes of service.

The practical limitations to the use of this type of generator are in general the same as for rotary converters. A large number of poles is not desirable, and therefore it is not well adapted for high frequencies or low speeds. This restricts its use for direct connection to slow-speed engines, and makes the belted type most common.

Double-current generators are suitable for plants in districts in which both alternating and direct-current lighting and power circuits are to be supplied, and in which the variations in these two classes of service are quite pronounced. Such conditions are most usually met with in small stations. For combination plants from which city and suburban railway lines are to be operated, they are also particularly well adapted. The direct-current side may be used direct for the city, and the alternating-current side in connection with static and rotary converters for the suburban districts.

The New York Ship Building Company, of Camden, New Jersey, are now installing a plant consisting of 500-kilowatt, two-phase, twenty-five-cycle, alternating-current-direct-current generators. Until quite recently they operated their works with direct-current motors, but are now increasing their power service by the addition of induction motors. The new plant will enable them to handle both classes of lighting and power from the same generators. A notable feature in connection with this installation is that the aggregate horse-power of the motors is far in excess of the total capacity of the generators, an indication that the load on the individual motors is quite variable or intermittent. The alternating-current-direct-current generator is admirably adapted for these conditions. By its use the fluctuations in the total load are reduced to a minimum, permitting of the operation of machines of a smaller aggregate capacity than if the two classes of service were fed separately, thereby securing a higher efficiency and better regulation.

THE PRESIDENT: What action will you take upon this paper, gentlemen?

MR. BEAN: I move that the paper be received with the thanks of the meeting, and that it be spread upon the minutes.

The motion was carried.

THE PRESIDENT: Is there to be any discussion of this paper? If not, we have some rather important business to attend to in executive session, and we will adjourn this general meeting and go into executive session.

The meeting adjourned to executive session.

EXECUTIVE SESSION

THE PRESIDENT: We will now hear the report of the committee on nominations.

MR. HUNTLEY: Mr. President and Gentlemen: Your committee would respectfully report that it offers in nomination for the officers of the association for the ensuing year the following gentlemen:

For president, Lieutenant James Blake Cahoon.

For first vice-president, Louis A. Ferguson.

For second vice-president, W. Worth Bean.

For members of the executive committee, to serve until the close of the twenty-sixth convention:

Charles B. Hunt, London, Ontario.

Ernest H. Davis, Williamsport, Pennsylvania.

Henry L. Doherty, New York City.

MR. SCOVIL: I move that the secretary be instructed to cast the ballot of the association for the gentlemen nominated.

The motion was carried, and the secretary duly cast the ballot.

THE PRESIDENT: I declare these gentlemen duly elected. I will ask Mr. Insull and Mr. Huntley to escort Mr. Cahoon to the chair.

Gentlemen, I have the great pleasure of introducing to you your new president, Mr. J. B. Cahoon, who, I am sure, will reflect great credit upon the organization during the ensuing year.

MR. CAHOON: Gentlemen, I suppose the new president, when he takes the chair, is expected to make a speech. I only want to say one or two words with reference to the work that has come in this convention. I think this convention has been one of the most promising, and one that is to be most fruitful in results, of any convention I have ever attended. The work outlined for the coming year is such that I do not believe the president of the association is going to have quite as easy a time as he has usually had in the past. We have taken up the subjects of accounting and meter rates, and these two matters should be pressed forward to completion.

The question of cost is an important one in view of what Mr. Huntley has said, which I think is borne out by many of the companies in other sections of the country, that is, that only twenty-three and one-half per cent of the companies in New York state are paying dividends. The question of the determination of the cost of our product, therefore, certainly deserves more consideration than has been given it in the past.

Another matter that seems to be forging rapidly to the front is the question that we were discussing to-day—that of municipal ownership. In December of this year, the League of American Municipalities meets in Charlestown, South Carolina, and in the mean time we have to formulate some plan whereby we can secure what we went after last year, namely, the co-operation of the league in the determination of the costs of municipally-operated plants, or else get them to do the baby act—quit.

That seems to be, in general, the outline of the work that is to be taken up. I want to say a word further in regard to the use of the offices of the association in New York. Last year I suggested that when any of the smaller plants were making changes in their systems, as many of them are doing, they send to the secretary a plan of their changes. Many of the small plants can not afford to employ electrical engineers to design their work for them, but they do need the assistance of the association in such matters as these to get on their feet. I am in hopes that this suggestion will be taken to heart. Further than that, I hope that the companies that are fighting this question of municipal ownership will not hesitate to go to the secretary of the association for data with which to fight safely and fully this question of municipal ownership.

Gentlemen, I thank you very much for the honor you have conferred upon me in electing me as your president.

PRESIDENT CARNES: Gentlemen, I now have the pleasure of introducing to you your first vice-president, Mr. Louis A. Ferguson, of Chicago.

MR. FERGUSON: Mr. President and Gentlemen: I wish to thank you for the honor you have conferred upon me in electing me to the office of first vice-president of this association, and I trust I may be able to fill the duties of the office to the entire satisfaction of the members of the association. I shall endeavor to do so.

PRESIDENT CARNES: We will now hear from Mr. W. Worth Bean, who has been duly elected second vice-president of the association.

MR. BEAN: Mr. President and Gentlemen: I desire to extend to you my heartfelt thanks for this high compliment, and will say to you that I shall try in the future, as I have done in the past, to do all I can for the central stations represented in this association.

PRESIDENT CARNES: We come now to the newly-elected members of the executive committee. Mr.

Charles B. Hunt, of London, Ontario, is the first-named gentleman on the list. He is not present. Mr. Ernest H. Davis, of Williamsport, Pennsylvania, is the next member.

MR. DAVIS: Mr. President and Gentlemen: All I can say is that I will do the best I can in the future as in the past.

PRESIDENT CARNES: Last, but not least in importance, is Mr. Henry L. Doherty.

MR. DOHERTY: I thank the association for electing me as a member of the executive committee, and shall do the best I can to serve your interests to your satisfaction.

I want at this time to say a few words about the work that is to be done by your arc lamp committee. Last year a committee was appointed to determine the photometric values of various arc lamps. That committee submitted its report to this convention. The work can not be carried on without expense. The individual members of the association subscribed something like half the amount of money used by the committee this past year. We have work in sight that will require an expenditure of one thousand dollars more. We hope to carry our work beyond that, and we hope to find some means of getting the money without bothering the association.

There are many things that we had to cover in our report that we have not spoken of in open meeting. One point, particularly, is some investigations that will put us on a little better footing with incandescent street lighting, which has certainly gained wonderfully in favor during the last few years. We need money to carry on this work, and we ask the members of the association to help us procure it, or we ask the association as a whole to provide it for us. If the association does not feel inclined to provide it, we will do the best we can to get it anyhow; but we all have a good deal to do in carrying on the work of the committee, and hope to make it a very full work. We brought out no names of manufacturers in our present report. Some of the work that we have done has not been reported upon. It would have been practically of no benefit to the association, but these results will be of immense benefit to the fraternity as a whole. Some manufacturers are making goods that are so bad that they were too bad to consider, and they do not know it. By letting the manufacturers that stand at the bottom of the list know where they stand (and I see no objection to letting each man know where he stands, but not letting his competitors know), it will benefit the product.

The form of arc lamps that gives the best results will probably never be determined except by committee work. No manufacturer seems inclined to take the matter up, and none of our central station men can take up a work requiring such exhaustive research. I do not care to make a motion, but will leave the matter to your consideration, and I ask your careful consideration of what should be done as to providing means for the further work of this committee. We have work, which is for the benefit of the central station men, that will cost in the neighborhood of a thousand dollars.

MR. INSULL: I move that a circular letter be sent to the active and associate members, asking them to subscribe to a fund for the purpose of carrying on various electrical tests, and that subscriptions be limited to amounts not to exceed fifty dollars.

The motion was carried.

President Carnes: I wish to express my gratitude for the high compliment you paid me in electing me as your president, and especially for your patient indulgence with my shortcomings and lack of ability to serve you as our former presidents have done. While I have done the best I could, I realize how little that has been, and I am very, very grateful to you for your kind indulgence.

Mr. Insull: I move that the president be empowered to appoint a committee to bring in at the next annnal meeting a change of our by-laws in relation to the dues; the dues to be graded according to the size or capitalization of the company that is a a member of the association.

The motion was carried.

President Cahoon: The report of the committee on standard candle power of incandescent lamps has just been handed to me. It is as follows:

REPORT OF THE COMMITTEE ON STANDARD CANDLE POWER OF INCANDESCENT LAMPS

The committee has the honor to report that since the last convention it has made material progress toward getting the details of standardization worked out.

The recent tendency has been toward a somewhat closer classification than was adopted by the association in pursuance of the committee's last report.

A number of stations are now demanding a range of candle power of from fifteen to seventeen, instead of from fourteen and one-half to seventeen and one-half as previously adopted. We believe that such course of classification is desirable, but are not prepared definitely to recommend it until proper standards and apparatus have come into more general use than at present.

With respect to sources of standards, your committee desires to call earnest attention to a measure now pending before Congress for the establishment of a national standardizing bureau, corresponding in its functions to the German Reichsanstalt, that would be able to furnish authoritative standards to all who should desire them, and your committee respectfully recommends that the National Electric Light Association—as a body—indorse the establishment of such a standardizing bureau, and communicate its indorsement to Honorable James H. Southard, chairman of the house committee on coinage, weights and measures.

Such a source for standards of light will be much more satisfactory and authoritative than anything that could otherwise be obtained, and its value to our association and to the art in general can hardly be overestimated.

Pending the establishment of such a government institution, your committee is arranging to have sixteen-candle-power lamps, of 110 and 220 volts, prepared at Columbia University, New York City, in pursuance of your committee's specifications. We believe that these will at least furnish a uniform and available standard of excellent quality.

These lamps will be furnished in pairs, at the cost of preparation, to such members of the National Electric Light Association as may desire them, and orders may be placed with the secretary of the association for such standards, which will be put through as promptly as possible.

The general method of standardization of these lamps will be that laid out in the report of the American Institute of Electrical Engineers on the subject.

With respect to photometric apparatus and methods, your committee is preparing for publication a specification and drawings for a standard photometer room and its equipment, and has under construction a standard form of simple photometer.

We have examined, during the past year, the forms of standard and portable photometers that are now on the market, and while some of them are capable of giving excellent results, we deem it wise to furnish specifications for a complete photometer room in which other photometers can be installed, together with directions for their use in such manner as to obtain from them the best results.

Without anticipating too much of the detail of these specifications, it is our belief that the standards should be run when practicable from a storage battery, or other separate steady source of electromotive force, obviating as far as possible the need of rheostatic control of the standard lamp. When such a source is not available, the standard and lamp to be tested should be operated off the same circuit, with a proper rheostat for bringing the voltage of the standard to its rated value.

With respect to methods of use of photometers, we desire to call attention most emphatically to the fact that photometers must be put in working adjustment by rotating the standard lamp at its rated voltage in the place that during testing will be occupied by lamps to be tested.

Photometers based on a fixed position of a standard lamp in which this precaution is not observed, we deem to be unreliable on account of errors of screen and personal errors, which can only be eliminated by treating the standard and the lamps to be tested in precisely the same manner.

Moreover, we desire to call attention to the desirability of investigating carefully the candle-power scales and the rheostats arbitrarily controlling the voltage in some forms of photometers now furnished. They are immensely convenient when in adjustment, but should not be used without testing their adjustment.

At the present time, we believe that the rotation of the lamp on the vertical axis is sufficient, although when lamp filaments are of more uniform characteristics than at present, arrangements for measuring zonal distribution of light may be desirable.

We believe that the time has come for careful photometric tests of all samples rather than for merely maximum and minimum tests, since lamp manufacture has so far advanced that if the maximum and minimum tests only were to be used, there might be a strong tendency on the part of the manufacturer to work toward the inferior or superior limit.

With respect to uniform wattage of lamps, at a given rated candle-power, we recognize the fact that the desire of stations as to closeness of wattage rating varies somewhat, but earnestly recommend that no variation from the nominal wattage of a sixteen-candle-power lamp greater than two and one-half watts on either side of such rating should be permitted.

With regard to method of sampling, we should recommend the testing of ten lamps taken promiscuously from each barrel, all of which must fall within the limits heretofore adopted by the association. We believe that any lot of lamps not standing this test should be totally rejected, and do not believe that any scheme permitting a greater variation can be productive of anything except bad lamps.

This sampling should be supplemented by test burning of lamps to determine their qualities with respect to life; but at the present time the art is not in such a state as to justify us in recommending any uniform and definite standard, although we believe that such recommendation should form a part of the subsequent work of your committee.

Finally, we would urge upon the members of the association the desirability of supplying themselves with standard lamps, which can, in the near future, be ordered at any time through the secretary; and we shall shortly have forwarded through the secretary, to all members, a copy of the specifications already referred to.

Respectfully submitted,

Committee { LOUIS BELL, Chairman
JAS. I. AYER
CALVIN W. RICE }

MR. INSULL: I move that the report be accepted and the work of the committee continued as outlined.

The motion was carried.

THE PRESIDENT: We will now have the report of the secretary and treasurer.

The secretary read the following report:

REPORT OF SECRETARY AND TREASURER

RECEIPTS

Active membership dues	$2,725 00	
Associate " "	980 00	
		$3,705 00
Sale Report Twenty-second Convention	225 00	
" badges " " "	45 00	
Advertisements in proceedings	345 00	
Received from Finance Committee	472 91	
" Account Lamp Committee (Photometric Investigation)	320 00	
Received Account Municipal Investigation Fund	1,745 00	
" for Postage	3 10	
" from Publications	47 42	
		3,203 43
Total Receipts		$6,908 43
Balance in bank January 1, 1899	$2,357 39	
" " petty cash January 1, 1899	7 42	
		2,364 72
		$9,273 15

DISBURSEMENTS

Salary of Secretary	$1,000 00	
Office rent	420 00	
Stenography and typewriting (including report of twenty-second convention)	1,414 66	
Printing and stationery (including proceedings and papers read at meeting)	1,288 41	
Postage and telegrams	162 42	
Traveling expenses	90 75	
Sundry "	51 04	
Badges	116 92	
Municipal Fund	40 68	
Arc Lamp Committee	320 00	
		4,904 60
Total Disbursements		$4,368 55
Balance in bank January 1, 1900	$4,330 79	
" " petty cash January 1, 1900	37 76	
		$4,368 55

ASSETS

Cash as above statement	$4,368 55
Office furniture as appraised by Finance Committee	215 00
Accounts receivable	90 00
	$4,673 55

LIABILITIES—None.

Respectfully submitted,

GEO. F. PORTER,

Secretary and Treasurer.

The meeting then adjourned.

APPENDIX

BY PERMISSION OF THE

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS,

HAVEMEYER BUILDING,
26 CORTLANDT STREET,

NEW YORK, N. Y.
JUNE, 1899.

[COPYRIGHT 1898.]

REPORT OF THE COMMITTEE ON STANDARDIZATION.

[Accepted by the INSTITUTE, June 26th, 1899.]

To the Council of THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

GENTLEMEN: Your committee on Standardization begs to submit the following report, covering such subjects as have been deemed of pressing and immediate importance, and which are of such a nature that general agreement may be expected upon them.

While it is the opinion of the committee that many other matters might advantageously have been considered, as, for example, standard methods of testing, yet it has been deemed inexpedient to attempt to cover in a single report more than is here submitted.

Yours respectfully,

FRANCIS B. CROCKER, Chairman.
CARY T. HUTCHINSON.
A. E. KENNELLY.
JOHN W. LIEB, JR.
CHARLES P. STEINMETZ.
LEWIS B. STILLWELL.
ELIHU THOMSON.

GENERAL PLAN.

Efficiency. Sections 1 to 24.
(I) Commutating Machines, Sections 6 to 11.
(II) Synchronous Machines, " 10 to 11.
(III) Synchronous Commutating Machines, " 12 to 15.
(IV) Rectifying Machines, " 16 to 17.
(V) Stationary Induction Apparatus, " 18 to 19.
(VI) Rotary Induction Apparatus, " 20 to 23.
(VII) Transmission Lines, 24.
Rise of Temperature. Sections 25 to 31.
Insulation. Sections 32 to 41.
Regulation. Sections 42 to 61.
Variation and Pulsation. Sections 62 to 65.
Rating. Sections 66 to 73.
Classification of Voltages and Frequencies. Sections 74 to 78.
Overload Capacities. Sections 79 to 82.
Appendices. (I) Efficiency.
(II) Apparent Efficiency.
(III) Power Factor and Inductance Factor.
(IV) Notation.
(V) Table of Sparking Distances.

Electrical Apparatus will be treated under the following heads:

I. *Commutating Machines*, which comprise a constant magnetic field, a closed-coil armature, and a multi, segmental commutator connected thereto.

Under this head may be classed the following: Direct-current generators; direct-current motors; direct-current boosters; motor generators; dynamotors; converters and closed-coil arc machines.

A booster is a machine inserted in series in a circuit to change its voltage, and may be driven either by an electric motor, or otherwise. In the former case it is a motor booster.

A motor-generator is a transforming device consisting of two machines; a motor and a generator mechanically connected together.

A dynamotor is a transforming device combining both motor and generator action in one magnetic field with two armatures or with an armature having two separate windings.

For converters, see III.

II. *Synchronous Machines*, which comprise a constant magnetic field, and an armature receiving or delivering alternating currents in synchronism with the motion of the machine; *i. e.*, having a frequency equal to the product of the number of pairs of poles and the speed of the machine in revolutions per second.

III. *Synchronous Commutating Machines*—These include: First, synchronous converters: *i.e.*, converters from alternating to direct, or from direct to alternating current, and, second, double-current generators; *i. e.*, generators producing both direct and alternating currents.

A converter is a rotary device transforming electric energy from one form into another without passing it through the intermediary form of mechanical energy.

A converter may be either:

a. A direct-current converter, converting from a direct current to a direct current or

b. A synchronous converter, formerly called a rotary converter, converting from an alternating to a direct current, or vice versa.

Phase converters are converters from an alternating-current system to an alternating-current system of the same frequency but different phase.

Frequency converters are converters from an alternating-current system of one frequency to an alternating-current system of another frequency, with or without changes of phase.

IV. *Rectifying Machines, or Pulsating-Current Generators,* which produce a unidirectional current of periodically varying strength.

V. *Stationary Induction Apparatus, i.e.,* stationary apparatus changing electric energy from one form into another, without passing it through an intermediary form of energy. These comprise:

a. Transformers, or stationary induction apparatus in which the primary and secondary windings are electrically insulated from each other.

b. Auto-transformers, formerly called compensators: *i.e.,* stationary induction apparatus in which part of the primary winding is used as a secondary winding; or conversely.

c. Potential regulators, or stationary induction apparatus having a coil in shunt, and a coil in series with the circuit, so arranged that the ratio of transformation between them is variable at will.

These may be divided into:

1. Compensator potential regulators, in which the number of turns of one of the coils is changed.

2. Induction potential-regulators, in which the relative positions of primary and secondary coils is changed.

3. Magneto potential-regulators, in which the direction of the magnetic flux with respect to the coils is changed.

d. Reactive coils, or Reactance coils, formerly called choking coils; *i.e.,* stationary induction apparatus used to produce impedance of phase displacement.

VI. *Rotary Induction Apparatus*, which consist of primary and secondary windings rotating with respect to each other. They comprise:

a. Induction motors.
b. Induction generators.
c. Frequency changers.
d. Rotary phase converters.

EFFICIENCY.

1. The "efficiency" of an apparatus is the ratio of its net power output to its gross power input.[1]

2. Electric power should be measured at the terminals of the apparatus.

3. In determining the efficiency of alternating-current apparatus, the electric power should be measured when the current is in phase with the electromotive force, unless otherwise specified, except when a definite phase difference is inherent in the apparatus, as in induction motors, etc.

4. Mechanical power in machines should be measured at the pulley, gearing, coupling, etc., thus excluding the loss of power in said pulley, gearing or coupling, but including the bearing friction and windage. The magnitude of bearing friction and windage may be considered as independent of the load. The loss of power in the belt and the increase of bearing friction due to belt tension, should be excluded. Where, however, a machine is mounted upon the shaft of a prime mover, in such a manner that it cannot be separated therefrom, the frictional losses in bearings and in windage, which ought, by

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[1] An exception should be noted in the case of storage batteries or apparatus for storing energy, in which the efficiency, unless otherwise qualified, should be understood as the ratio of the energy output to the energy intake in a normal cycle.

definition, to be included in determining the efficiency, should be excluded, owing to the practical impossibility of determining them satisfactorily. The brush friction, however, should be included.

a. Where a machine has auxiliary apparatus, such as an exciter, the power lost in the auxiliary apparatus should not be charged to the machine but to the plant consisting of machine and auxiliary apparatus taken together. The plant efficiency in such cases should be distinguished from the machine efficiency.

5. The efficiency may be determined by measuring all the losses individually and adding their sum to the output to derive the input, or subtracting their sum from the input to derive the output. All losses should be measured at, or reduced to, the temperature assumed in continuous operation, or in operation under conditions specified. (See section 25 to 31.)

In order to consider the application of the foregoing rules to various machines in general use, the latter may be conveniently divided into classes as follows:

I. *Commutating Machines.*

6. In commutating machines the losses are:

a. Bearing friction and windage. (See section 4.)

b. Molecular magnetic friction, and eddy currents in iron and copper. These losses should be determined with the machine on open circuit, and at a voltage equal to the rated voltage $+ I r$ in a generator, and $- I r$ in a motor, where I denotes the current strength, and r denotes the internal resistance of the machine. They should be measured at the correct speed and voltage, since they do not usually vary in proportion to the speed or to any definite power of the voltage.

c. Armature resistance losses, $I^2 r'$, where I is the current strength in the armature, and r' is the resistance between armature brushes, excluding the resistance of brushes and brush contacts.

d. Commutator brush friction.

e. Commutator brush-contact resistance. It is desirable to point out that with carbon brushes the losses (*d*) and (*e*) are usually considerable in low-voltage machines.

f. Field excitation. With separately excited fields, the loss of power in the resistance of the field coils alone should be considered. With shunt fields or series fields, however, the loss of power in the accompanying rheostat should also be included, the said rheostat being considered as an essential part of the machine, and not as separate auxiliary apparatus.

(*b*) and (*c*) are losses in the armature or "armature losses;" (*d*) and (*e*) "commutator losses;" (*f*) "field losses."

7. The difference between the total losses under load and the sum of the losses above specified should be considered as "load losses," and are usually trivial in commutating machines of small field distortion. When the field distortion is large, as is shown by the necessity for shifting the brushes between no load and full load, or with variations of load, these load losses may be considerable, and should be taken into account. In this case the efficiency may be determined either by input and output measurements, or the load losses may be estimated by the method of Section II.

8. Boosters should be considered and treated like other direct-current machines in regard to losses.

9. In motor-generators, dynamotors or converters, the efficiency is the $\frac{\text{electric output}}{\text{electric input.}}$

II. *Synchronous Machines.*

10. In synchronous machines the output or input should be measured with the current in phase with the terminal electromotive force, except when otherwise expressly specified.

Owing to the uncertainty necessarily involved in the approximation of load losses, it is preferable, whenever possible, to determine the efficiency of synchronous machines by input and output tests.

11. The losses in synchronous machines are:

a. Bearing friction and windage. (See Section 4.)

b. Molecular magnetic friction and eddy currents in iron, copper and other metallic parts. These losses should be determined at open circuit of the machine at the rated speed and at the rated voltage, $+ I r$ in a synchronous generator, $- I r$ in a synchronous motor, where $I =$ current in armature, $r =$ armature resistance. It is undesirable to compute these losses from observations made at other speeds or voltages.

These losses may be determined either by driving the machine by a motor, or by running it as a synchronous motor, and adjusting its fields so as to get minimum current input and measuring the input by wattmeter. The former is the preferable method, and in polyphase machines the latter method is liable to give erroneous results in consequence of unequal distribution of currents in the different circuits caused by inequalities of the impedance of connecting leads, etc.

c. Armature-resistance loss, which may be expressed by $p\ I^2\ r$; where $r =$ resistance of one armature circuit or branch, $I =$ the current in such armature circuit or branch, and $p =$ the number of armature circuits or branches.

d. Load losses as defined in section 7. While these losses cannot well be determined individually, they may be considerable and, therefore, their joint influence should be determined by observation. This can be done by operating the machine on short circuit and at full-load current, that is, by determining what may be called the "short-circuit core loss." With the low-field intensity and great lag of current existing in this case, the load losses are usually greatly exaggerated.

One-third of the short-circuit core loss may, as an approximation, and in the absence of more accurate information, be assumed as the load loss.

e. Collector-ring friction and contact resistance. These are generally negligible, except in machines of extremely low voltage.

f. Field excitation. In separately-excited machines, the $I^2\ r$ of the field coils proper should be used. In self-exciting machines, however, the loss in the field rheostat should be included. (See section 6 *f.*)

III. *Synchronous Commutating Machines*

12. In synchronous converters, the power on the alternating-current side is to be measured with the current in phase with the terminal electromotive force, unless otherwise specified.

13. In double-current generators, the efficiency of the machine should be determined as a direct-current generator in accordance with section 6, and as an alternating-current generator in accordance with section

11. The two values of efficiency may be different, and should be clearly distinguished.

14. In synchronous converters the losses should be determined when driving the machine by a motor. These losses are:

a. Bearing friction and windage, see section 4.

b. Molecular magnetic friction and eddy currents in iron, copper and metallic parts. These losses should be determined at open circuit and at the rated terminal voltage, no allowance being made for the armature resistance, since the alternating and the direct currents flow in opposite directions.

c. Armature resistance. The loss in armature is $q\ I^2\ r$, where $I =$ direct current in armature, $r =$ armature resistance and q, a factor which is equal to 1.37 in single-phasers, 0.56 in three-phasers, 0.37 in quarter-phasers and 0.26 in six-phasers.

d. Load losses. The load losses should be determined in the same manner as described in section 11 *d*, with reference to the direct-current side.

e and *f.* Losses in commutator and collector friction and brush-contact resistance. (See sections 6 and 11.)

g. Field excitation. In separately-excited fields, the $I^2 r$ loss in the field coils proper should be taken, while in shunt and series fields the rheostat loss should be included, except where fields and rheostats are intentionally modified to produce effects outside of the conversion of electric power, as for producing phase displacement for voltage control. In this case twenty-five per cent of the $I^2 r$ loss in the field proper at non-inductive alternating circuit should be added as proper estimated allowance for normal rheostat losses. (See section 6 *f.*)

15. Where two similar synchronous machines are

available, their efficiency can be determined by operating one machine as a converter from direct to alternating, and the other as a converter from alternating to direct, connecting the alternating sides together, and measuring the difference between the direct-current input, and the direct-current output. This process may be modified by returning the output of the second machine through two boosters into the first machine and measuring the losses. Another modification might be to supply the losses by an alternator between the two machines, using potential regulators.

IV. *Rectifying Machines or Pulsating-Current Generators*

16. These include: Open-coil arc machines, constant-current rectifiers, constant-potential rectifiers.

The losses in open-coil arc machines are essentially the same as in sections 6 to 9 (closed-coil commutating machines.) In alternating-current rectifiers, however, the output must be measured by wattmeter and not by voltmeter and ammeter, since, owing to the pulsation of current and electromotive force, a considerable discrepancy may exist between watts and volt-amperes, amounting to as much as ten or fifteen per cent.

17. In constant-current rectifiers, transforming from constant-potential alternating to constant direct current by means of constant-current transformers and rectifying commutators, the losses in the transformers are to be included in the efficiency and have to be measured when operating the rectifier, since in this case the losses are generally greater than when feeding an alternating secondary circuit. In constant-current transformers the load losses are usually larger

than in constant-potential transformers and thus should not be neglected.

The most satisfactory method of determining the efficiency in rectifiers is to measure electric input and electric output by wattmeter. The input is usually not non-inductive, owing to a considerable phase displacement and to wave distortion. For this reason the apparent efficiency should also be considered, since it is usually much lower than the true efficiency. The power consumed by the synchronous motor or other source driving the rectifier should be included in the electric input.

V. *Stationary Induction Apparatus*

18. Since the efficiency of induction apparatus depends upon the wave shape of electromotive force, it should be referred to a sine wave of electromotive force, except where expressly specified otherwise. The efficiency should be measured with non-inductive load, and at rated frequency, except where expressly specified otherwise. The losses are:

a. Molecular magnetic friction and eddy currents measured at open circuit and at rated voltage — Ir, where $I =$ rated current, $r =$ resistance of primary circuit.

b. Resistance losses, the sum of the $I^2 r$ of primary and of secondary in a transformer, or of the two sections of the coil in the compensator or auto-transformer, where $I =$ current in the coil or section of coil, $r =$ resistance.

c. Load losses, *i.e.*, eddy currents in the iron and especially in the copper conductors, caused by the current. They should be measured by short-circuiting the secondary of the transformer and impressing upon the primary an electromotive force sufficient to send full-load current through the transformer. The loss in the transformer under these conditions measured by wattmeter gives the load losses $+ I^2 r$ losses in both primary and secondary coils.

d. Losses due to the methods of cooling, as power consumed by the blower in air-blast transformers, and power consumed by the motor-driving pumps in oil or water-cooled transformers. Where the same cooling apparatus supplies a number of transformers or is installed to supply future additions, allowance should be made therefor.

19. In potential regulators the efficiency should be taken at the maximum voltage for which the apparatus is designed, and with non-inductive load, unless otherwise specified.

VI. *Rotary Induction Apparatus*

20. Owing to the existence of load losses and since the magnetic density in the induction motor under load changes in a complex manner, the efficiency should be determined by measuring the electric input by wattmeter and the mechanical output at the pulley, gear, coupling, etc.

21. The efficiency should be determined at the rated frequency and the input measured with sine waves of impressed electromotive force.

22. The efficiency may be calculated from the apparent input, the power factor, and the power output. The same applies to induction generators. Since phase displacement is inherent in induction machines, their apparent efficiency is also important.

23. In frequency changers; *i. e.*, apparatus transforming from a polyphase system to an alternating system of different frequency, with or without a change in the number of phases, and phase converters; *i. e.*,

apparatus converting from an alternating system, usually single phase to another alternating system usually polyphase, of the same frequency, the efficiency should also be determined by measuring both output and input.

VII. *Transmission Lines*

24. The efficiency of transmission lines should be measured with non-inductive load at the receiving end, with the rated receiving pressure and frequency, also with sinusoidal impressed electromotive forces, except where expressly specified otherwise, and with the exclusion of transformers or other apparatus at the ends of the line.

RISE OF TEMPERATURE

General Principles

25. Under regular service conditions, the temperature of electrical machinery should never be allowed to remain at a point at which permanent deterioration of its insulating material takes place.

26. The rise of temperature should be referred to the standard conditions of a room-temperature of twenty-five degrees centigrade, a barometric pressure of 760 millimetres and normal conditions of ventilation; that is, the apparatus under test should neither be exposed to draught nor enclosed, except where expressly specified.

27. If the room-temperature during the test differs from twenty-five degrees centigrade, the observed rise of temperature should be corrected by one-half per cent for each degree centigrade.[2] Thus with a room-.

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[2] This correction is also intended to compensate, as nearly as is at present practicable, for the error involved in the assumption of a constant temperature coefficient of resistivity; *i. e.* 0.4 per cent per degree centigrade taken with varying initial temperatures.

temperature of thirty-five degrees centigrade, the observed rise of temperature has to be decreased by five per cent, and with a room-temperature of fifteen degrees centigrade, the observed rise of temperature has to be increased by five per cent. The thermometer indicating the room-temperature should be screened from thermal radiation emitted by heated bodies, or from draughts of air. When it is impracticable to secure normal conditions of ventilation on account of an adjacent engine, or other sources of heat, the thermometer for measuring the air temperature should be placed so as fairly to indicate the temperature which the machine would have if it were idle, in order that the rise of temperature determined shall be that caused by the operation of the machine.

28. The temperature should be measured after a run of sufficient duration to reach practical constancy. This is usually from six to eighteen hours, according to the size and construction of the apparatus. It is permissible, however, to shorten the time of the test by running a lesser time on an overload in current and voltage, then reducing the load to normal, and maintaining it thus until the temperature has become constant.

In apparatus intended for intermittent service, as railway motors, starting rheostats, etc., the rise of temperature should be measured after a shorter time, depending upon the nature of the service, and should be specified.

In apparatus which by the nature of their service may be exposed to overload, as railway converters, and in very high voltage circuits, a smaller rise of temperature should be specified than in apparatus not liable to overloads or in low voltage apparatus. In apparatus built for conditions of limited space, as railway motors, a higher rise of temperature must be allowed.

29. In electrical conductors, the rise of temperature should be determined by their increase of resistance. For this purpose the resistance may be measured either by galvanometer test, or by drop-of-potential method. A temperature co-efficient of 0.4 per cent per degree centigrade, may be assumed for copper.[3] Temperature elevations measured in this way are usually in excess of temperature elevations measured by thermometers.

30. It is recommended that the following maximum values of temperature elevation should not be exceeded:

Commutating machines, rectifying machines, and synchronous machines.

Field and armature, by resistance, fifty degrees centigrade.

Commutator and collector rings and brushes, by thermometer, fifty-five degrees centigrade.

Bearings and other parts of machine by thermometer, forty degrees centigrade.

Rotary induction apparatus:

Electric circuits, fifty degrees centigrade, by resistance.

Bearings and other parts of the machine forty degrees centigrade, by thermometer.

In squirrel cage or short-circuited armatures, fifty-five degrees centigrade, by thermometer, may be allowed.

Transformers for continuous service—electric circuits by resistance, fifty degrees centigrade, other parts, by thermometer, forty degrees centigrade, under conditions of normal ventilation.

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[3] By the formula $R_T = R_t\ (1 + 0.004\ \theta)$. Where R_t is the resistance at room-temperature, R_T the resistance when heated, and θ the temperature elevation $(T\text{-}t)$ in degrees centigrade.

Reactive coils, induction and magneto regulators—electric circuits by resistance fifty-five degrees centigrade, other parts by thermometer forty-five degrees centigrade.

Where a thermometer, applied to a coil or winding, indicates a higher temperature elevation than that shown by resistance measurement, the thermometer indication should be accepted. In using the thermometer, care should be taken so to protect its bulb as to prevent radiation from it, and, at the same time, not to interfere seriously with the normal radiation from the part to which it is applied.

31. In the case of apparatus intended for intermittent service, the temperature elevation which is attained at the end of the period corresponding to the term of full load, should not exceed fifty degrees centigrade by resistance in electric circuits. In the case of transformers intended for intermittent service, or not operating continuously at full load but continuously in circuit as in the ordinary case of lighting transformers, the temperature elevation above the surrounding air-temperature should not exceed fifty degrees centigrade by resistance in electric circuits and forty degrees centigrade by thermometer in other parts, after the period corresponding to the term of full load. In this instance, the test load should not be applied until the transformer has been in circuit for a sufficient time to attain the temperature elevation due to core loss. With transformers for commercial lighting, the duration of the full-load test may be taken as three hours, unless otherwise specified. In the case of railway, crane and elevator motors, the

conditions of service are necessarily so varied that no specific period corresponding to the full-load term can be stated.

INSULATION

32. The ohmic resistance of the insulation is of secondary importance only, as compared with the dielectric strength, or resistance to rupture by high voltage.

Since the ohmic resistance of the insulation can be very greatly increased by baking, but the dielectric strength is liable to be weakened thereby, it is preferable to specify a high dielectric strength rather than a high-insulation resistance. The high-voltage test for dielectric strength should always be applied.

Insulation Resistance

33. Insulation resistance tests should, if possible, be made at the pressure for which the apparatus is designed.

The insulation resistance of the complete apparatus must be such that the rated voltage of the apparatus will not send more than $\frac{1}{1,000,000}$ of the full-load current, at the rated terminal voltage, through the insulation. Where the value found in this way exceeds one megohm, one megohm is sufficient.

Dielectric Strength

34. The dielectric strength or resistance to rupture should be determined by a continued application of an alternating electromotive force for one minute. The source of alternating electromotive force should be a transformer of such size that the charging current of the apparatus as a condenser does not exceed

twenty-five per cent of the rated capacity of the transformer.

35. The high-voltage tests should not be applied when the insulation is low, owing to dirt or moisture, and should be applied before the machine is put into commercial service.

36. It should be pointed out that tests at high voltages considerably in excess of the normal voltages are admissible on new machines, to determine whether they fulfill their specifications, but should not be made subsequently at a voltage much exceeding the normal, as the actual insulation of the machine may be weakened by such tests.

37. The test for dielectric strength should be made with the completely assembled apparatus and not with its individual parts, and the voltage should be applied as follows:

First. Between electric circuits and surrounding conducting material, and

Second. Between adjacent electric circuits, where such exist, as in transformers.

The tests should be made with a sine wave of electromotive force, or where this is not available, at a voltage giving the same striking distance between needle points in air, as a sine wave of the specified electromotive force, except where expressly specified otherwise. As needles, new sewing needles should be used. It is recommended to shunt the apparatus during the test by a spark gap of needle points set for a voltage exceeding the required voltage by ten per cent.

A table of approximate sparking distances is given in Appendix V.

38. The following voltages are recommended for

apparatus not including transmission lines or switchboards:

Rated Terminal Voltage.	Capacity.	Testing Voltage.
Not exceeding 400 volts............	Under 10 K.W....	1,000 volts.
" " " "	10 K.W. and over.	1,500 "
400 and over, but less than 800 volts	Under 10 K.W....	1,500 "
" " " " "	10K.W. and over..	2,000 "
800 " " " 1,200 "	Any	3,500 "
1,200 " " " 2,500 "	Any	5,000 "
2,500 "	Any	Double the normal rated voltages.
Synchronous motor fields and fields of converters started from the alternating-current side........................		5,000 volts.

Alternator-field circuits should be tested under a breakdown test voltage corresponding to the rated voltage of the exciter, and referred to an output equal to the output of the alternator; *i. e.*, the exciter should be rated for this test as having an output equal to that of the machine it excites.

Condensers should be tested at twice their rated voltage and at their rated frequency.

The values in the table above are effective values, or square roots of mean square reduced to a sine wave of electromotive force.

39. In testing insulation between different electric circuits, as between primary and secondary of transformers, the testing voltage must be chosen corresponding to the high-voltage circuit.

40. In transformers of from 10,000 volts to 20,000 volts, it should be considered as sufficient to operate the transformer at twice its rated voltage, by connecting first the one, and then the other terminal of the high-voltage winding to the core and to the low-voltage winding. The test of dielectric resistance between the low-voltage winding and the core should be in accordance with the recommendation in section 38, for similar voltages and capacities.

41. When machines or apparatus are to be operated in series, so as to employ the sum of their

separate electromotive forces, the voltage should be referred to this sum, except where the frames of the machines are separately insulated both from ground and from each other.

REGULATION

42. The term regulation should have the same meaning as the term "inherent regulation," at present frequently used.

43. The regulation of an apparatus intended for the generation of constant potential, constant current, constant speed, etc., is to be measured by the maximum variation of potential, current, speed, etc., occurring within the range from full load to no load, under such constant conditions of operation as give the required full-load values, the condition of full load being considered in all cases as the normal condition of operation.

44. The regulation of an apparatus intended for the generation of a potential, current, speed, etc., varying in a definite manner between full load and no load, is to be measured by the maximum variation of potential current, speed, etc., from the satisfied condition, under such constant conditions of operation as give the required full-load values.

If the manner in which the variation in potential, current, speed, etc., between full load and no load is not specified, it should be assumed to be a simple linear relation; *i. e.*, undergoing uniform variation between full load and no load.

The regulation of an apparatus may, therefore, differ according to its qualification for use. Thus the regulation of a compound-wound generator specified as a constant-potential generator will be different from that it possesses when specified as an over-compounded generator.

45. The regulation is given in percentage of the full-load value of potential, current, speed, etc., and the apparatus should be steadily operated during the test under the same conditions as at full load.

46. The regulation of generators is to be determined at constant speed; of alternating apparatus at constant impressed frequency.

47. The regulation of a generator-unit, consisting of a generator united with a prime-mover, should be determined at constant conditions of the prime mover; *i. e.*, constant steam pressure, head, etc. It would include the inherent speed variations of the prime-mover. For this reason the regulation of a generator-unit is to be distinguished from the regulation of either the prime-mover, or of the generator contained in it, when taken separately.

48. In apparatus generating, transforming or transmitting alternating currents, regulation should be understood to refer to non-inductive load, that is, to a load in which the current is in phase with the electromotive force at the output side of the apparatus, except where expressly specified otherwise.

49. In alternating apparatus receiving electric power, regulation should refer to a sine wave of electromotive force, except where expressly specified otherwise.

50. In commutating machines, rectifying machines and synchronous machines, as direct-current generators and motors, alternating-current and polyphase generators, the regulation is to be determined under the following conditions:

a. At constant excitation in separately excited fields.

b. With constant resistance in shunt field circuits and

c. With constant resistance shunting series fields; *i. e.*, the field adjustment should remain constant, and should be so chosen as to give the required full-load voltage at full-load current.

51. In constant-potential machines, the regulation is the ratio of the maximum difference of terminal voltage from the rated full-load value (occurring within the range from full load to open circuit) to the full-load terminal voltage.

52. In constant-current machines, the regulation is the ratio of the maximum difference of current from the rated full-load value (occurring within the range from full-load to short-circuit), to the full-load current.

53. In constant-power machines, the regulation is the ratio of maximum difference of power from the rated full-load value (occurring within the range of operation specified) to the rated power.

54. In over-compounded machines, the regulation is the ratio of the maximum difference in voltage from a straight line connecting the no-load and full-load values of terminal voltage as function of the current, to the full-load terminal voltage.

55. In constant-speed continuous-current motors, the regulation is the ratio of the maximum variation of speed from its full-load value (occurring within the range from full load to no load) to the full-load speed.

56. In transformers, the regulation is the ratio of the rise of secondary terminal voltage from full load to no load (at constant primary impressed terminal voltage) to the secondary terminal voltage.

57. In induction motors, the regulation is the

ratio of the rise of speed from full load to no load (at constant impressed voltage), to the full-load speed.

The regulation of an induction motor is, therefore, not identical with the slip of the motor, which is the ratio of the drop in speed from synchronism, to the synchronous speed.

58. In converters, dynamotors, motor generators, and frequency changers, the regulation is the ratio of the maximum difference of terminal voltage at the output side from the rated full-load voltage (at constant impressed voltage and at constant frequency), to the full-load voltage on the output side.

59. In transmission lines, feeders, etc., the regulation is the ratio of maximum voltage difference at the receiving end, between no load and full non-inductive load, to the full-load voltage at the receiving end, with constant voltage impressed upon the sending end.

60. In steam engines, the regulation is the ratio of the maximum variation of speed in passing from full load to no load (at constant steam pressure at the throttle) to the full-load speed.

61. In a turbine or other water motor, the regulation is the ratio of the maximum variation of speed from full load to no load (at constant head of water; *i. e.*, at constant difference of level between tail race and head race), to the full-load speed.

Variation and Pulsation

62. In prime movers which do not give an absolutely uniform rate of rotation or speed, as in steam engines, the "variation" is the maximum angular displacement in position of the revolving member expressed in degrees, from the position it would occupy with uniform rotation, and with one revolution as 360 degrees; and the pulsation is the

ratio of the maximum change of speed in an engine cycle to the average speed.

63. In alternators or alternating-current circuits in general, the variation is the maximum difference in phase of the generating wave of electromotive force from a wave of absolutely constant frequency, expressed in degrees, and is due to the variation of the prime-mover. The pulsation is the ratio of the maximum change of frequency during an engine cycle to the average frequency.

64. If $n =$ number of poles, the variation of an alternator is $\frac{n}{2}$ times the variation of its prime-mover if direct-connected, and $\frac{n}{2}p$ times the variation of the prime-mover, if rigidly connected thereto in the velocity ratio p.

65. The pulsation of an alternating current circuit is the same as the pulsation of the prime-mover of its alternator.

RATING

66. Both electrical and mechanical power should be expressed in kilowatts, except when otherwise specified. Alternating-current apparatus should be rated in kilowatts on the basis of non-inductive condition; *i. e.*, with the current in phase with the terminal voltage.

67. Thus the electric power generated by an alternating-current apparatus equals its rating only at non-inductive load, that is when the current is in phase with the terminal voltage.

68. Apparent power should be expressed in kilovolt-amperes as distinguished from real power in kilowatts.

69. If a power-factor other than 100 per cent is specified, the rating should be expressed in kilovolt-amperes and power-factor, at full load.

70. The full-load current of an electric generator is that current which with the rated full-load terminal voltage gives the rated kilowatts, but in alternating-current apparatus only at non-inductive load.

71. Thus in machines in which the full-load voltage differs from the no-load voltage, the full-load current should refer to the former.

If $P =$ rating of an electric generator and $E =$ full-load terminal voltage, the full-load current is:

$I = \frac{P}{E}$ in a continuous-current machine or single-phase alternator,

$I = \frac{P}{E\sqrt{3}}$ in a three-phase alternator.

$I = \frac{P}{2E}$ in a quarter-phase alternator.

72. Constant-current machines, such as series arc-light generators, should be rated in kilowatts based on terminal volts and amperes at full load.

73. The rating of a fuse or circuit breaker should be the current-strength at which it will open the circuit, and not the working-current strength.

Classification of Voltages and Frequencies

74. In direct-current, low-tension generators, the following average terminal voltages are in general use and are recommended:

125 volts. 250 volts. 550 volts.

75. In direct-current, and alternating-current, low-

pressure circuits, the following average terminal voltages are in general use and are recommended:

110 volts. 220 volts.

In direct-current power circuits, for railway and other service, 500 volts may be considered as standard.

76. In alternating current, high-pressure circuits at the receiving end, the following pressures are in general use, and are recommended:

1,000 volts. 2,000 volts. 3,000 volts. 6,000 volts.
10,000 volts. 15,000 volts. 20,000 volts.

77. In alternating-current high-pressure generators, or generating systems the following terminal voltages are in general use, and are recommended:

1,150 volts. 2,300 volts. 3,450 volts.

These pressures allow of a maximum drop in transmission of fifteen per cent of the pressure at the receiving end. If the drop required is greater than fifteen per cent, the generator should be considered as special.

78. In alternating-current circuits, the following approximate frequencies are recommended as desirable:

25 ~ or 30 ~ 40 ~ 60 ~ 120 ~(4)

These frequencies are already in extensive use and it is deemed advisable to adhere to them as closely as possible.

Overload Capacities

79. All guarantees on heating, regulation, sparking, etc., should apply to the rated load, except where expressly specified otherwise, and in alternating-current

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4. The frequency of 120 ~ may be considered as covering the already existing commercial frequencies between 120 ~ and 140 ~, and the frequency of 60 ~ as covering the already existing commercial frequencies between 60 ~ and 70 ~.

apparatus to the current in phase with the terminal electromotive force, except where a phase displacement is inherent in the apparatus.

80. All apparatus should be able to carry a reasonable overload without self-destruction by heating, sparking, mechanical weakness, etc., and with an increase of temperature elevation not exceeding fifteen degrees centigrade, above those specified for full loads. (See sections 25 to 31.)

81. Overload guarantees should refer to normal conditions of operation regarding speed, frequency, voltage, etc., and to non-inductive conditions in alternating apparatus, except where a phase displacement is inherent in the apparatus.

82. The following overload capacities are recommended:

First. In direct-current generators and alternating-current generators, twenty-five per cent for one-half hour.

Second. In direct-current motors and synchronous motors, twenty-five per cent for one-half hour, fifty per cent for one minute; except in railway motors and other apparatus intended for intermittent service.

Third. Induction motors, twenty-five per cent for one-half hour, fifty per cent for one minute.

Fourth. Synchronous converters, fifty per cent for one-half hour.

Fifth. Transformers, twenty-five per cent for one-half hour; except in transformers connected to apparatus for which a different overload is guaranteed, in which case the same guarantees shall apply for the transformers as for the apparatus connected thereto.

Sixth. Exciters of alternators and other synchronous machines, ten per cent more overload than is required for the excitation of the synchronous machine at its guaranteed overload, and for the same period of time.

APPENDIX I

EFFICIENCY.

Efficiency of Phase-Displacing Apparatus

In apparatus producing phase displacement, as, for example, synchronous compensators, exciters of induction generators, reactive coils, condensers, polarization cells, etc., the efficiency should be understood to be the ratio of the volt-ampere activity to the volt-ampere activity plus power loss.

The efficiency may be calculated by determining the losses individually, adding to them the volt-ampere activity, and then dividing the volt-ampere activity by the sum.

First. In synchronous compensators and exciters of induction generators, the determination of losses is the same as in other synchronous machines under sections 10 and 11.

Second. In reactive coils the losses are molecular friction, eddy losses, and I^2r loss. They should be measured by wattmeter. The efficiency of reactive coils should be determined with a sine wave of impressed electromotive force, except where expressly specified otherwise.

Third. In condensers, the losses are due to dielectric hysteresis and leakage and should be determined by wattmeter with a sine wave of electromotive force.

Fourth. In polarization cells, the losses are those due to electric resistivity and a loss in the electrolyte of the nature of chemical hysteresis, and are usually very considerable. They depend upon the frequency, voltage, and temperature, and should be determined with a sine wave of impressed electromotive force, except where expressly specified otherwise.

APPENDIX II

Apparent Efficiency

In apparatus in which a phase displacement is inherent to their operation, apparent efficiency should be understood as the ratio of net power output to volt-ampere input.

Such apparatus comprise induction motors, reactive synchronous converters, synchronous converters controlling the voltage of an alternating-current system, self-exciting synchronous motors, potential regulators, and open magnetic circuit transformers, etc.

Since the apparent efficiency of apparatus generating electric power depends upon the power factor of the load, the apparent efficiency, unless otherwise specified, should be referred to a load power factor of unity.

APPENDIX III

Power Factor and Inductance Factor

The power factor in alternating circuits or apparatus may be defined as the ratio of the electric power, in watts, to volt-amperes.

The inductance factor is to be considered as the ratio of wattless volt-amperes to total volt-amperes.

Thus, if $p =$ power factor, $q =$ inductance factor, then

$$p^2 + q^2 = 1$$

The power factor is the

$$\frac{\text{(energy component of current or E.M.F.)}}{\text{(total current or E. M. F.)}} = \frac{\text{true power}}{\text{volt-amperes.}}$$

and the inductance factor is the

$$\frac{\text{(wattless component of current or E. M. F.)}}{\text{(total current or E. M. F.)}}$$

Since the power factor of apparatus supplying electric power depends upon the power factor of the load, the power factor of the load should be considered as unity, unless otherwise specified.

APPENDIX IV

The following notation is recommended:

E, e, voltage, electromotive force, potential difference
I, i, current
P, power
Φ, magnetic flux
$\mathcal{B}$, magnetic density
R, r, resistance
X, x, reactance
Z, z, impedance
L, l, inductance
C, c, capacity

Vector quantities when used should be denoted by capital italics.

APPENDIX V

Table of Sparking Distances in Air between Opposed Sharp Needle-Points, for Various Effective Sinusoidal Voltages, in inches and in centimetres.

Kilovolts Sq. Root of Mean Square	Distance.		Kilovolts Sq. Root of Mean Square.	Distance.	
	Inches	Cms.		Inches	Cms.
5	0.225	0.57	60	4.65	11.8
10	0.47	1.19	70	5.85	14.9
15	0.725	1.84	80	7.1	18.0
20	1.0	2.54	90	8.35	21.2
25	1.3	3.3	100	9.6	24.4
30	1.625	4.1	110	10.75	27.3
35	2.0	5.1	120	11.85	30.1
40	2.45	6.2	130	12.95	32.9
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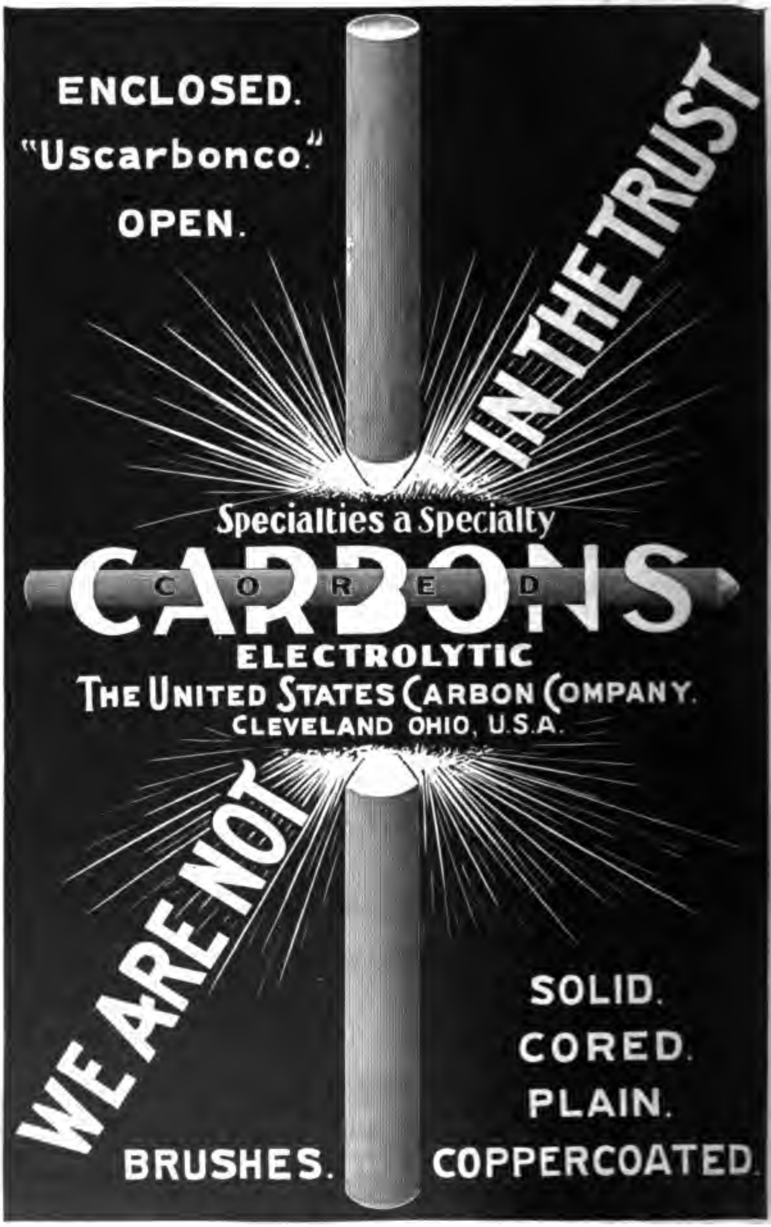

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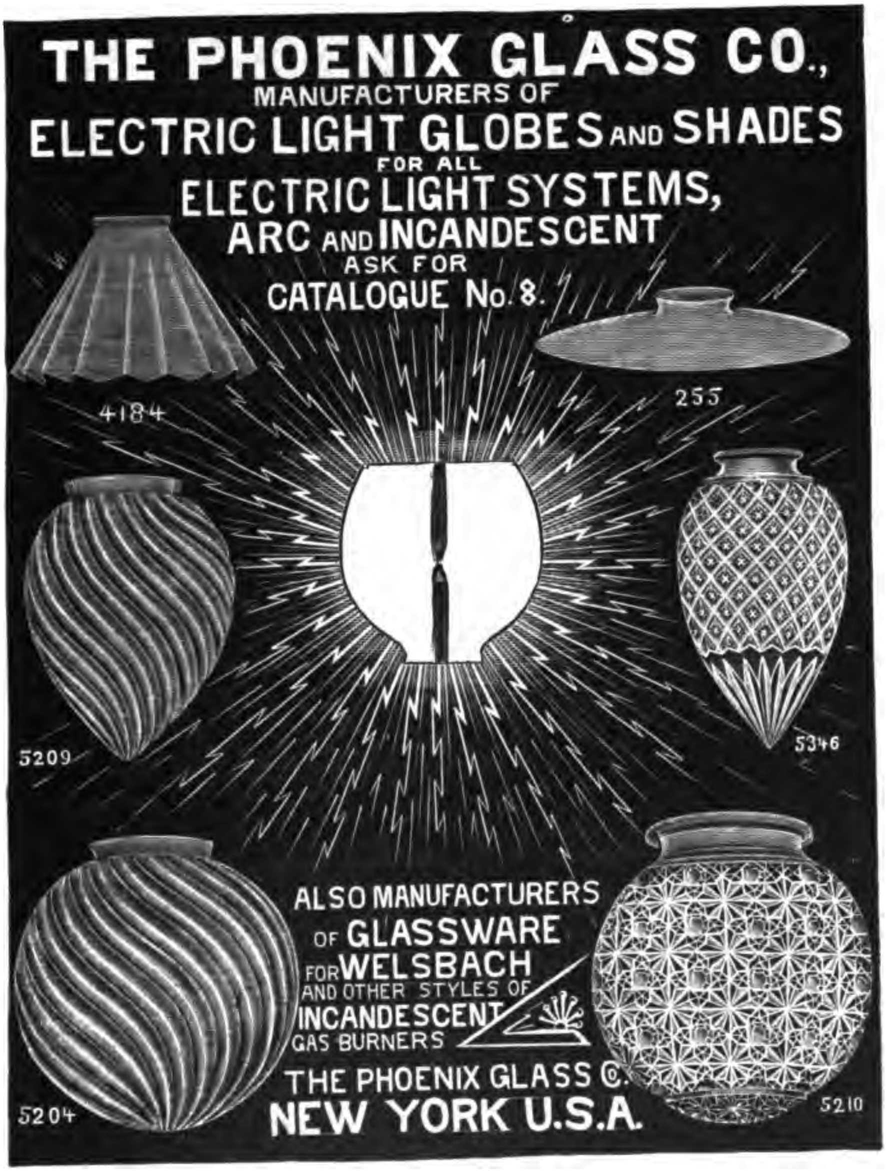

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